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POLLUTION OF PRYOR CREEK AND FORT GIBSON RESERVOIR IN THE VICINTY OF PRYOR, OKLAHOMA

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

May 1958

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POLLUTION OF
PRYOR CREEK AND FORT GIBSON RESERVOIR
IN THE VICINITY OF
PRYOR, OKLAHOMA

U.S. Department of Health, Education, and Welfare
Public Health Service

Region VII Office
Dallas, Texas

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Cincinnati, Ohio

May 1956

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C. Field Procedures

D. Hydrological Data

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I. Husky, Planning & Resources Board
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POLLUTION OF PRYOR CREEK AND FT. GIBSON RESERVOIR IN THE VICINITY OF PRYOR, OKLAHOMA

INTRODUCTION

The Governor's Coordinating Committee on Pollution Control sponsored a study of pollution of Pryor Creek and Grand River in the vicinity of Pryor, Oklahoma, during the late summer and early fall of 1956.

Evaluation of effects of municipal and industrial pollution in Pryor Creek on water quality and uses in Ft. Gibson Reservoir, an impoundment on Grand River, was one major objective of the study. Principal effects reported were difficulties with water treatment and with taste and odor in the Wagoner, Oklahoma, municipal water supply, and fish kills in Ft. Gibson Lake below the mouth of Pryor Creek. A second major objective of the study was to provide a basis for estimating reductions in pollution needed to prevent adverse effects on water quality and uses.

Numerous local, State, and Federal agencies cooperated in the field work. Cooperating agencies and individuals are listed in the front of this report. At the invitation of the Committee the U. S. Public Health Service accepted principal responsibility for supervision of technical aspects of the study and preparation of a report.

A first draft of a report on the pollution study was submitted for consideration by the Technical Subcommittee of the Coordinating Committee in March 1957. While not complete in all details, the first draft included analysis and interpretation of data that was considered adequate to permit definition of the pollution problems, designation of the sources of wastes responsible for pollutional effects, and estimation of permissible discharges of waste constituents that would not cause excessive interference with essential uses of Ft. Gibson Reservoir.

The Technical Subcommittee accepted the tabulations of basic data in the first draft of the report, but withheld action on the text. The Subcommittee directed that the basic data be submitted to a consultant chosen by 2 of the plants involved for independent analysis and interpretation. The report by the consultant was to be completed within 90 days, or by about the middle of June 1957. The final official report on the study was to be postponed to permit consideration of the consultant's report. This report was received in January 1958.

In the interim, comments on the March 1957, first draft report have been received from the members of the Technical Subcommittee. These comments and the consultant's report have received consideration in preparation of the present report.

THE AREA

The Grand (Neosho) River rises in Kansas and flows into Oklahoma near the northeastern corner of the State (Figure 1). A few miles below the State line the river enters the upper end of Grand Lake O' the Cherokees. This large storage impoundment is under the jurisdiction of the Grand River Dam Authority, which operates the reservoir for production of power.

About 35 miles below Pensacola Dam, which impounds Grand Lake O' the Cherokees, Grand River enters the upper end of Ft. Gibson Reservoir. This impoundment, about 40 miles east of Tulsa, is under the jurisdiction of the U. S. Corps of Engineers, and it also is operated for power production. After passing through Ft. Gibson Reservoir, which is about 45 miles long, Grand River discharges through generators at the dam and flows about 7 miles to join the Arkansas River near Muskogee.

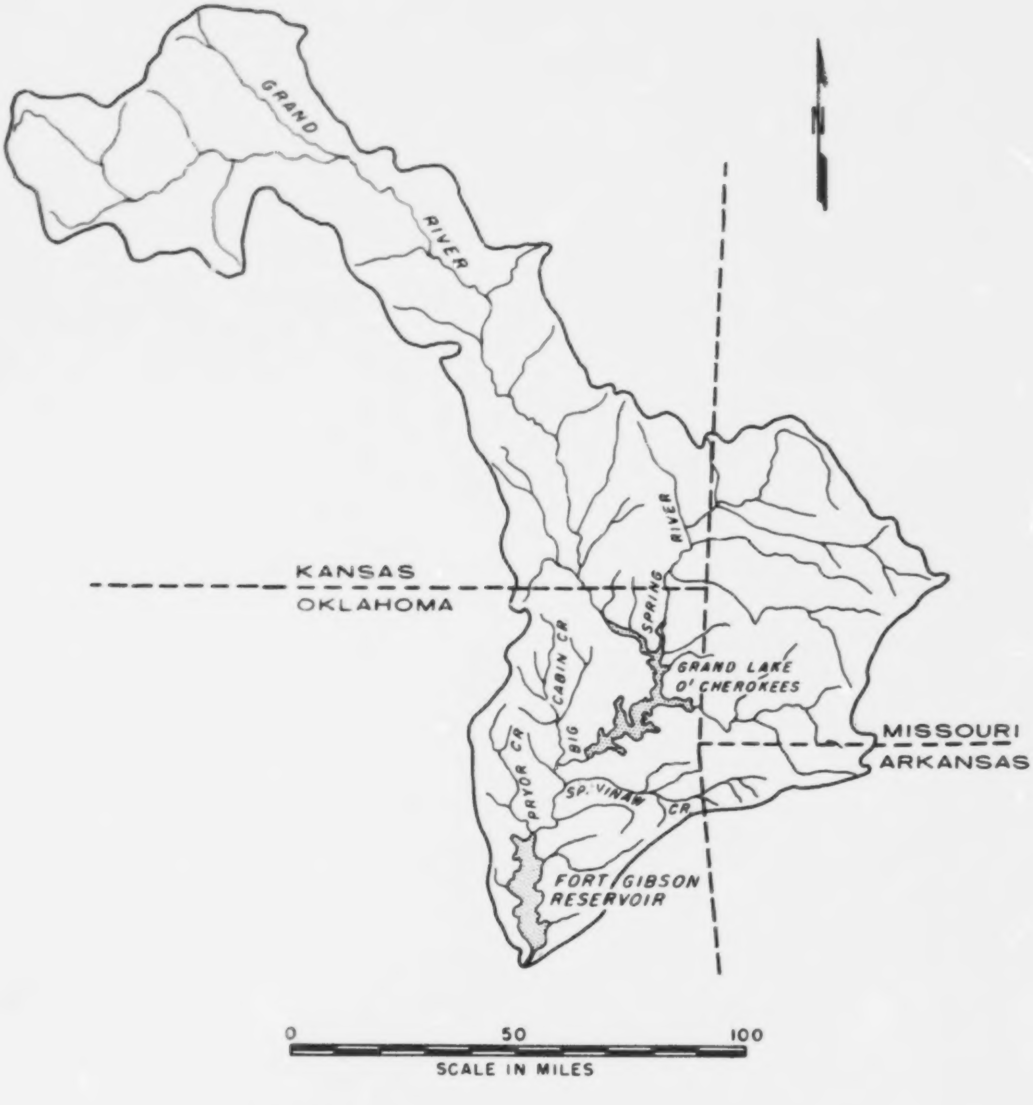
The Grand River Dam Authority is considering construction of a third dam, Markham Ferry, on Grand River just above Ft. Gibson Reservoir. This dam would impound water up to the toe of Pensacola Dam.

Pryor Creek rises northeast of Pryor, flows west and then south of the town, and joins Ft. Gibson Reservoir near its upper end (Figure 2). The lower 3.5 miles of the creek are impounded by backwater from the reservoir. In the vicinity of Pryor the creek receives treated sewage from the town and wastes from several industries. This is the only area tributary to Grand River between Pensacola and Ft. Gibson dams in which there is an important concentration of sources of wastes.

Also on Pryor Creek is located the steam power plant of the Grand River Dam Authority. Cooling water is pumped from Grand River and discharges to Pryor Creek. This plant furnishes steam and water as well as electricity to the industrial complex adjacent to Pryor Creek. Availability of these services was an important consideration in decisions to locate the industries in this area.

Approximately midway down Ft. Gibson Reservoir (Figure 3) and about 15 miles below the mouth of Pryor Creek the town of Wagoner takes water for its municipal supply from the reservoir. At Ft. Gibson Dam, about 32 miles below the mouth of Pryor Creek, water is drawn from the reservoir for the municipal supply of Muskogee.

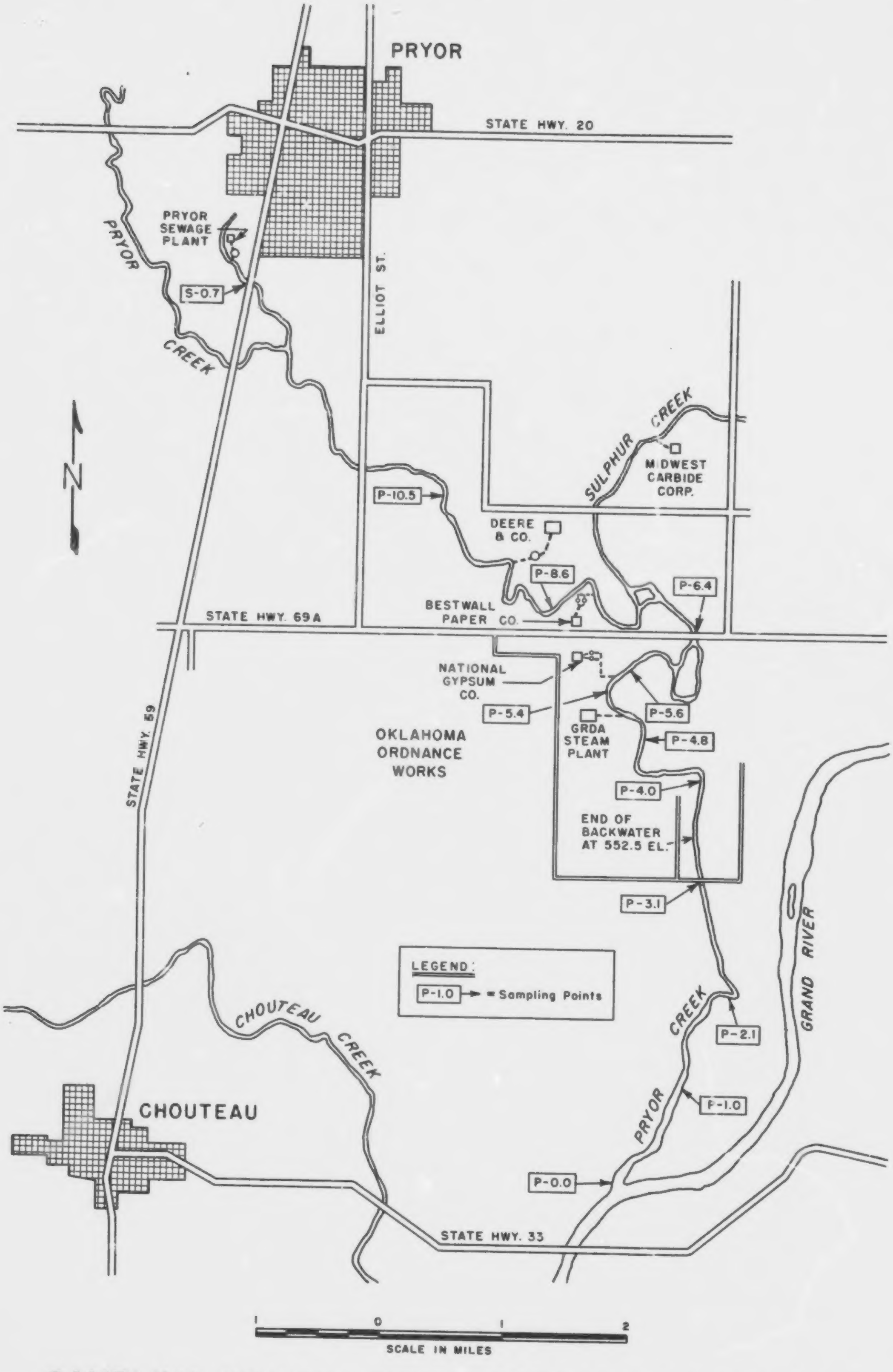
Tulsa takes water for its municipal supply from Spavinaw Lakes, which are nearly 20 miles farther from the city than is Ft. Gibson Reservoir. When this fast growing city's water supply requirements exceed the present source it is quite possible that Ft. Gibson Reservoir may receive consideration as an additional source of municipal water for Tulsa.


GRAND RIVER
KANSAS
OKLAHOMA
MISSOURI
ARKANSAS
SPRING RIVER
CABIN CR
BIG
PRYOR CR
GRAND LAKE O' CHEROKEES
SP. VINAW CR
FORT GIBSON RESERVOIR
N
0
50
100
SCALE IN MILES

GRAND RIVER DRAINAGE AREA

FIGURE 1

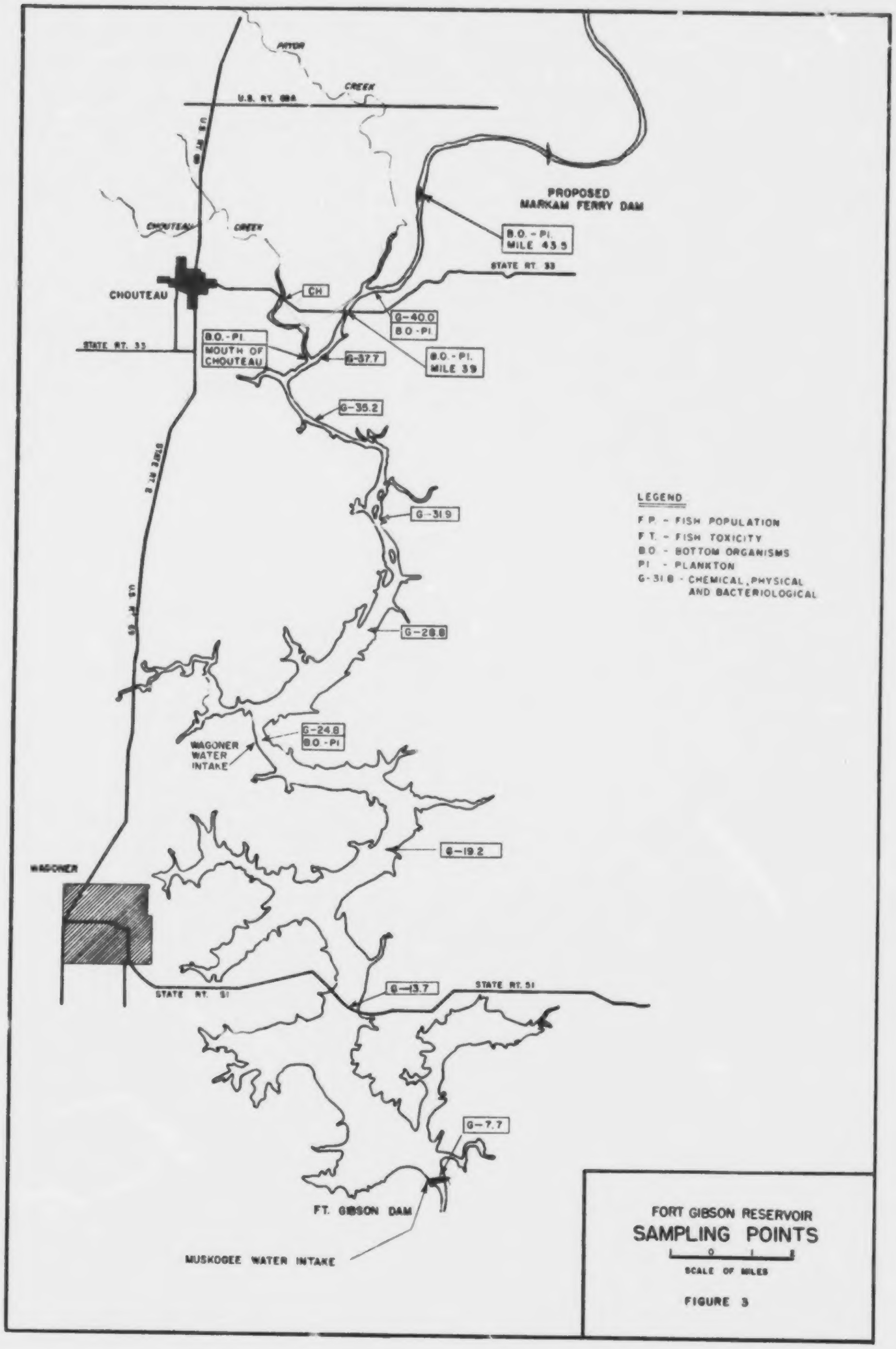
2-B


PRYOR
STATE HWY. 20
PRYOR SEWAGE PLANT
S-0.7
PRYOR CREEK
ELLIOT ST.
N
SULPHUR CREEK
MIDWEST CARBIDE CORP.
P-10.5
DEERE & CO.
P-8.6
P-6.4
BESTWALL PAPER CO.
STATE HWY. 69A
NATIONAL GYPSUM CO.
P-5.4
P-5.6
GRDA STEAM PLANT
P-4.8
OKLAHOMA ORDNANCE WORKS
P-4.0
END OF BACKWATER AT 552.5 EL.
STATE HWY. 59
P-3.1
LEGEND:
P-1.0 = Sampling Points
CHOUTEAU CREEK
PRYOR CREEK
GRAND RIVER
P-2.1
P-1.0
CHOUTEAU
P-0.0
STATE HWY. 33
1 0 1 2
SCALE IN MILES

SAMPLING POINTS - PRYOR CREEK AND VICINITY

FIGURE 2

2-C


PRYOR
CREEK
U.S. RT. 69A
U.S. RT. 69
PROPOSED
MARKAM FERRY DAM
CHOUTEAU
CREEK
B.O. - PI.
MILE 43.5
STATE RT. 33
CHOUTEAU
CH
G-40.0
B.O.-PI.
STATE RT. 33
B.O.-PI
MOUTH OF
CHOUTEAU
G-37.7
B.O.-PI.
MILE 39
G-35.2
STATE RT. 2
G-31.9
LEGEND
F.P. - FISH POPULATION
F.T. - FISH TOXICITY
B.O. - BOTTOM ORGANISMS
PI - PLANKTON
G-31.8 - CHEMICAL, PHYSICAL
AND BACTERIOLOGICAL
U.S. RT. 69
G-28.8
WAGONER
WATER
INTAKE
G-24.8
B.O.-PI
G-19.2
WAGONER
STATE RT. 51
G-13.7
STATE RT. 51
G-7.7
FT. GIBSON DAM
MUSKOGEE WATER INTAKE
0
1
2
SCALE OF MILES

FORT GIBSON RESERVOIR
SAMPLING POINTS

FIGURE 3

The recreational values of Ft. Gibson Reservoir are high. The clarity of its water and the rolling hills along its banks contribute to its scenic attractions. Sport fishes are abundant and catches are good. Located in a section of the State where large bodies of water are scarce the reservoir has become a major center of recreation for the area. Numerous shore facilities range from small fishing docks to the well equipped Sequoyah State Park with its large modern buildings (Figure 4). Large numbers of people enjoy fishing, swimming, boating and water skiing, especially in the lower end of the reservoir, during the warm season.

Both present and potential water supply and recreational uses of Ft. Gibson Reservoir require that the quality of its water be protected to allow it greatest possible contribution to the present and future welfare of the area through maximum development of these uses.

EVIDENCES OF POLLUTION

The major effects of pollution have been mentioned in the Introduction. More detailed information on these effects follows.

Municipal Water Supplies

Wagoner, Oklahoma

The town of Wagoner, with a 1950 population of 4,495, takes water from Ft. Gibson Reservoir about 15 miles below Pryor Creek, and about 17 miles above Ft. Gibson Dam. The water is treated in a conventional rapid sand filtration plant located on the bank of the reservoir. The water normally is chlorinated sufficiently to maintain a free chlorine residual of about 2 parts per million (ppm) for both bacterial disinfection and control of tastes and odors that occur in the reservoir water from time to time. Available description of the tastes and odors indicate that they probably are caused by algae rather than directly by industrial wastes. The industrial wastes, on the other hand, may contribute indirectly to the taste and odor problem by providing nutrients that support increased production of algae.

The principal evidence of pollution of the raw water has been interference with the chlorination process. The description of this difficulty by the water plant operator indicates that the interference probably is caused by ammonia in the raw water. When the difficulty occurs tests for residual chlorine appear to indicate that chloramines (compounds of chlorine and ammonia) are present in the treated water rather than the desired free chlorine. Chloramines are slower in bacteriacidal action than free chlorine, and generally are less effective in controlling taste and odor.

It is reported that the treatment plant processes frequently have not been successful in controlling tastes and odors in the treated water. This has occurred when it was impossible to chlorinate to a free chlorine residual even though chlorination equipment was operated at its full capacity of 20 ppm. The difficulty occurred most frequently in cold weather.

It was stated by the Wagoner Superintendent of Utilities that water consumers in Wagoner lost confidence in the municipal water supply to such an extent that many of them turned to bottled water for drinking.

It has been reported that rapidly fluctuating and high pH (balance between acid and alkaline constituents) of the raw water has caused difficulty in treatment. This may have been caused by irregular upstream discharges of large quantities of highly alkaline wastes. A pH of the raw water as high as 11.0 has been reported. This problem has been less severe recently than it was formerly.

Muskogee, Oklahoma

The water supply for this town of 37,289 population is taken from Ft. Gibson Reservoir through an intake incorporated in the dam about 15 feet below the water surface.

Difficulty in obtaining a free chlorine residual in this supply has been reported only once, for a few days. The problem does not appear to have been severe at that time.

No problems with fluctuating or otherwise abnormal pH have been reported here.

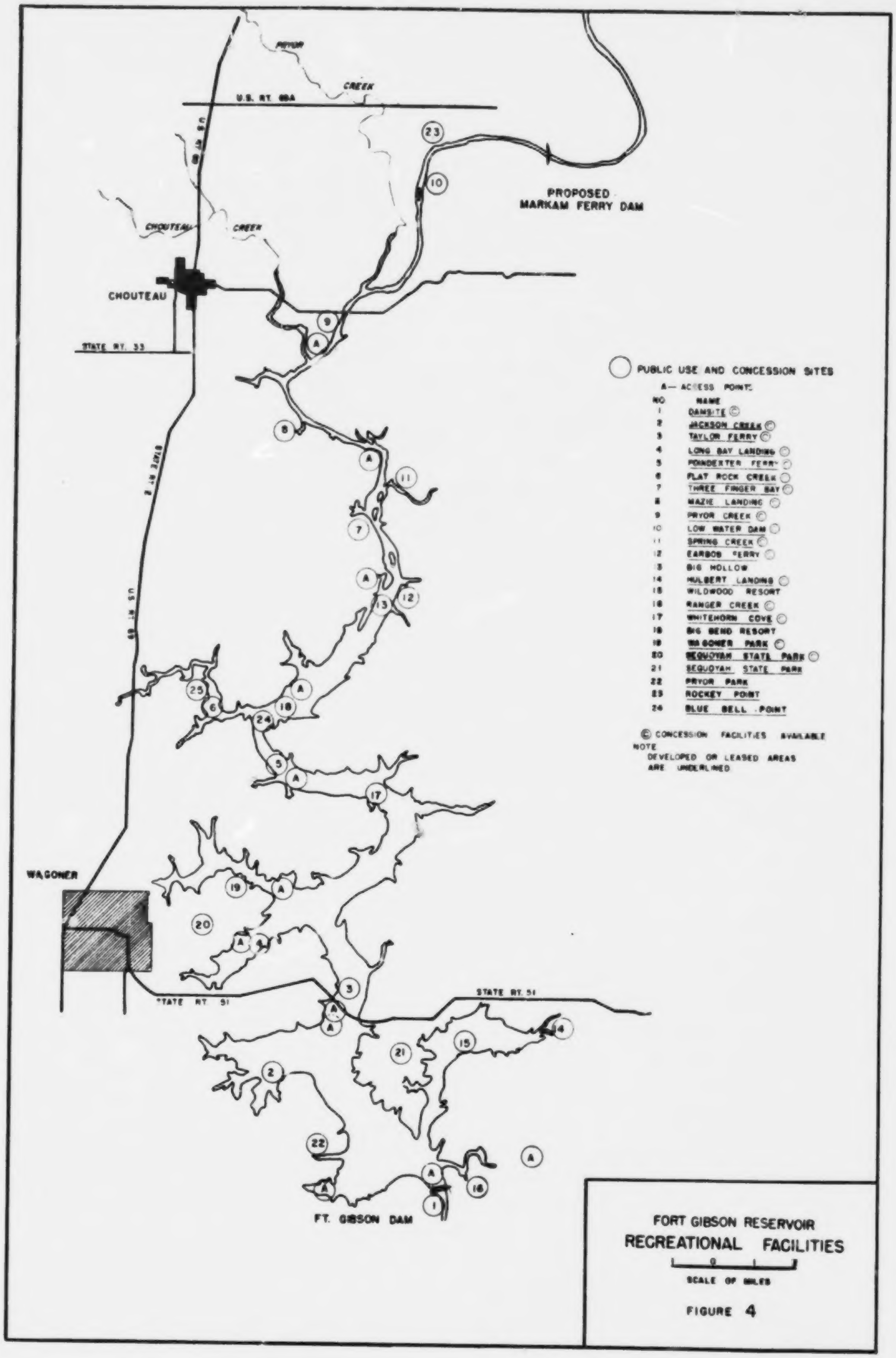
Fish Kills

There have been numerous fish kills in Fort Gibson Reservoir below the mouth of Pryor Creek. Records of the kills are not complete but they have occurred with sufficient frequency to indicate that pollution in Pryor Creek posed a continuing threat to fish in the reservoir.

The severity of reported kills has ranged from a few dead fish noted in the vicinity of the mouth of Pryor Creek to thousands of dead fish in the reservoir below the creek. On at least one occasion dying fish have been observed as far downstream as the Wagoner water intake, 15 miles downstream, and dead fish as far as 20 miles downstream.

The pattern of conditions preceding and during major kills

4-A


PRYOR
CREEK
U.S. RT. 69A
U.S. 69
PROPOSED
MARKAM FERRY DAM
CHOUTEAU
CREEK
CHOUTEAU
STATE RT. 33
STATE RT. 2
U.S. RT. 69
WAGONER
STATE RT. 51
STATE RT. 51
FT. GIBSON DAM
A
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
○ PUBLIC USE AND CONCESSION SITES
A— ACCESS POINTS
NO NAME
1 DAMSITE ©
2 JACKSON CREEK ©
3 TAYLOR FERRY ©
4 LONG BAY LANDING ©
5 POINDEXTER FERRY ©
6 FLAT ROCK CREEK ©
7 THREE FINGER BAY ©
8 MAZIE LANDING ©
9 PRYOR CREEK ©
10 LOW WATER DAM ©
11 SPRING CREEK ©
12 EARBOB FERRY ©
13 BIG HOLLOW
14 HULBERT LANDING ©
15 WILDWOOD RESORT
16 RANGER CREEK ©
17 WHITEHORN COVE ©
18 BIG BEND RESORT
19 WAGONER PARK ©
20 SEQUOYAH STATE PARK ©
21 SEQUOYAH STATE PARK
22 PRYOR PARK
23 ROCKEY POINT
24 BLUE BELL POINT
© CONCESSION FACILITIES AVAILABLE
NOTE
DEVELOPED OR LEASED AREAS
ARE UNDERLINED
SCALE OF MILES
0

FORT GIBSON RESERVOIR
RECREATIONAL FACILITIES

FIGURE 4

appears to have been similar in most cases. Many kills were preceded by moderate to prolonged periods of dry weather during which there was little or no natural flow in Pryor Creek above the town of Pryor. This permitted the creek to fill with wastes discharged to it at and below Pryor. Immediately preceding the kills moderate to heavy rainfalls occurred on the Pryor Creek watershed. The runoff into the creek resulting from these rains flushed the accumulated wastes suddenly into the reservoir. The accumulated wastes are relatively dark in color and their rapid discharge into the reservoir during a flushout can readily be detected in the clear reservoir water. One observer of a major fish kill reported that the reservoir water at a point immediately below Pryor Creek was dark for only about 4 hours while the wastes were being flushed out and fish were dying. This indicates the rapidity with which the large volumes of accumulated wastes can enter the reservoir.

Pryor Creek

The effects of pollution on Pryor Creek itself can be seen and smelled from the mouth of the creek to a point 8.6 miles upstream. The water appears black throughout this section. The odor of hydrogen sulfide is evident, especially in the 3.5 miles of impounded water at the lower end of the creek. Above the 8.6 mile point the creek is bright green because of excessive growths of algae nourished by constituents of wastes in the creek.

SOURCES OF WASTE

Waste water is discharged from 6 sources (Figure 2) into water courses of the Pryor Creek watershed in the vicinity of Pryor. Brief descriptions of the sources follow. More detailed information has been assembled and is recorded in the file of material on Pryor Creek and Ft. Gibson Reservoir.

Pryor Sewage

The sewage from the town of Pryor receives complete treatment in a conventional plant providing primary sedimentation, biological oxidation by trickling filters, final sedimentation, and sludge digestion and drying. Raw sewage is pumped to the primary settling tank and the treated sewage is pumped to a sewage stabilization pond.

The plant is overloaded both biochemically and hydraulicly. The sewage stabilization pond was added after the plant became overloaded in lieu of enlarged treatment plant facilities and to provide a higher degree of treatment than is normal in a conventional treatment plant. The higher degree of treatment was needed because of the lack of dilution in the small receiving stream.

On days when samples were collected at the plant the effects of hydraulic overload were noted. Undetermined, but relatively small, quantities of sewage bypassed the trickling filters and flowed directly from the primary to the secondary settling basin. In addition the effluent of the secondary settling basin exceeded the capacity of the final pump during peak flows, and a portion of the treated sewage bypassed the stabilization pond and flowed directly to the creek.

The lagoon effluent discharges to a small, unnamed tributary of Pryor Creek at a point 0.7 of a mile above the confluence of the two creeks, and 13.5 miles above the mouth of Pryor Creek.

Grand River Chemical Division, John Deere and Company

This plant manufactures synthetic ammonia and urea for agricultural uses. It started operations in August 1954. The basic methods used are the established processes for synthesis of nitrogen and hydrogen to form ammonia, and for conversion of ammonia to urea. In many details, however, this plant is a pioneer in adopting revisions of previous processes to improve yields and increase equipment capacities. Outstanding variations from previous processes involve increased temperatures and pressures at various points in the process.

During the latter half of September the plant production averaged 130 tons of ammonia and 110 tons of urea daily.

Wastes from the process flow to a lagoon with a theoretical retention of about 60 days. Temperature observations at several depths in the lagoon indicated that there was strong temperature stratification of the wastes. Since the temperature of the wastes entering the lagoon was relatively high it is probable that there was short circuting across the surface to the overflow outlet structure and that the actual retention was much shorter than the theoretical detention. The lagoon effluent flows through a ditch to enter a large pooled section of Pryor Creek at a point 9.6 miles above the mouth of the creek.

Principal known waste constituents of actual or potential importance in the stream study were ammonia, urea, sodium hydroxide and sulfuric acid. The sulfuric acid did not originate in the process but was applied to the lagoon to neutralize waste sodium hydroxide.

Another potentially important waste was the hexavalent chromium used in cooling water to inhibit corrosion. It was reported that the used cooling water was disposed underground through a well and did not reach Pryor Creek.

Bestwall Gypsum Company

This plant produces 3 types of paper for covering wallboard and lathing, and dry felt used as a base for tar paper and composition shingles. It started operation in August 1952.

During the first half of September total plant production averaged 196 tons of paper per day.

Principal raw fiber materials are reclaimed scrap paper, wood and a small amount of sulfite pulp. The sulfite pulp is obtained as prepared pulp from another source. No chemical digestion or de-inking is employed at the plant. The wood is disintegrated by steam cooking without use of chemicals. Other raw materials include small amounts of starch, glue, alum, rosin, dyes, and a proprietary alkaline compound.

Pulp fibers are reclaimed by savealls at 3 points in the process. Fiber losses are about 0.5 percent of product. The combined plant waste flows to one of 2 lagoons for settling. While one lagoon is in operation the other is closed for removal of accumulated fiber. Theoretical retention in either of the lagoons is about 12 hours.

The lagoon effluent flows through a ditch to enter Pryor Creek 8.0 miles above its mouth.

Principal waste constituents are dissolved and suspended organic materials . Most of the suspended organic material is wood fiber lost from the process.

Midwest Carbide Corporation

This plant produces calcium carbide from coke and lime. There are no liquid wastes from the electric furnace in which the two raw materials are reacted.

Cooling water used on the furnace has no contact with the materials processed, but a proprietary compound containing chromium is added for water conditioning. Used cooling water flows to a small pond and thence to Sulfur Creek which joins Pryor Creek 7.1 miles above its mouth.

During the period of field work Sulfur Creek was dry and the small flow of waste water from the plant either evaporated or seeped into the ground before reaching Pryor Creek. Water from Midwest Carbide exerted no influence on the condition of Pryor Creek during the study.

National Gypsum Corporation

This plant produces 3 types of paper for covering wallboard and lathing. It started operating in January 1952.

Raw fiber materials are reclaimed scrap paper, sulfite pulp, and ground wood pulp. The sulfite pulp is obtained as prepared pulp from another source, and the ground wood pulp is prepared at the plant. Neither chemical digestion nor de-inking is employed here. Other raw materials include small amounts of diatomaceous earth, dye, rosin, alum, starch, and a proprietary chlorophenol compound.

It was stated by plant personnel that production averaged about 180 tons of paper per day during the period the plant wastes were sampled.

Saveall reclamation of pulp fibers is quite effective at this plant, with losses being held to 0.2 percent of the product. Two lagoons are provided for the wastes. One is used to receive wastes during plant wash-up periods and the other receives the regular combined plant wastes. Theoretical retention in the latter is about 2.6 days.

The lagoon effluent flows through a ditch to join Pryor Creek 5.5 miles above its mouth.

Principal waste constituents are dissolved and suspended organic materials. Most of the suspended organic material is wood fiber lost from the process.

Grand River Dam Authority Steam Plant

The steam plant of the Grand River Dam Authority (GRDA) produces steam power to supplement that from the hydro plant at Pensacola Dam. In addition it provides steam and water, pumped from Grand River at the Low Water Dam just above Ft. Gibson Reservoir, to the industries located along Pryor Creek.

This power plant originally was built to serve the Oklahoma Ordnance Works, which was constructed during the war to manufacture explosives.

Most of the water discharged from the plant is that used for cooling. The waste stream also carries irregular discharges of wash water from the filters and sludge from the sedimentation basins at the water plant, and regeneration chemicals and wash water from the water softeners.

The waste water flows through a ditch to join Pryor Creek at a point 5.2 miles above the mouth of the creek.

Chemical content of the plant waste water is unimportant in the pollution problem on Pryor Creek. In fact the relatively clean water probably is beneficial through the dilution it provides for the wastes from other sources. It constitutes about 40 percent of the total flow of Pryor Creek during extended dry weather when there is no natural flow in the creek.

METHODS OF STUDY

Field study operations were centered in Pryor, where an office was established in an uptown commercial building, and three mobile trailer laboratories were located on property of and adjacent to the office of GRDA.

Brief descriptions of field and laboratory procedures follow. Details are given in Appendix C.

Sampling

Stations

All wastes discharging to Pryor Creek were sampled short distances from the points at which they entered the creek. At the Pryor sewage treatment plant samples were collected from the raw sewage and from all steps in the process. At the industrial plants having waste lagoons the lagoon influents and effluents were sampled.

Sampling stations on Pryor Creek for routine chemical analyses are shown in Figure 2. Those for biological examination appear in Figure 5.

Ft. Gibson stations for both chemical and biological samples are shown in Figure 3. Depths at which samples for chemical analyses were taken at these stations varied from one in the upper shallow end of the lake to 3 in the lower deep portion.

Grand Lake O' the Cherokees was sampled just above the dam. Spavinaw, Chouteau and Big Cabin creeks were sampled in the vicinities of their mouths.

Collection

Composite samples for chemical analyses were collected from all sources of wastes except Midwest Carbide Corporation. Frequencies of sampling and durations of compositing periods were varied to suit the types of wastes and variations in waste flow and composition. Sample portions were composited in proportion to waste discharge where flow fluctuations were significant.

Composites were collected on 3 days at the Pryor sewage plant, 4 at GRDA steam plant, 5 at each of the paper mills, and 6 at John Deere and Company.

Six to 7 grab samples for chemical analyses were collected at all Pryor Creek stations except P-6.4, where 3 were taken.

Grab samples for chemical analyses were collected from all Ft. Gibson stations and at all depths on 4 days.

Only 1 or 2 grab samples were collected in Grand Lake O' the Cherokees and in the creeks other than Pryor.

Biological sampling frequencies were more varied than that for chemical analyses. A minimum of 1 sample was collected at some stations and as many as 4 at others, depending on the biological importance of individual stations.

Chemical and Biological Procedures

Methods of examination generally followed recommendations of the Tenth Edition of "Standard Methods for the Examination of Water, Sewage and Wastes." For the few determinations not covered by Standard Methods reliable and recognized procedures were employed.

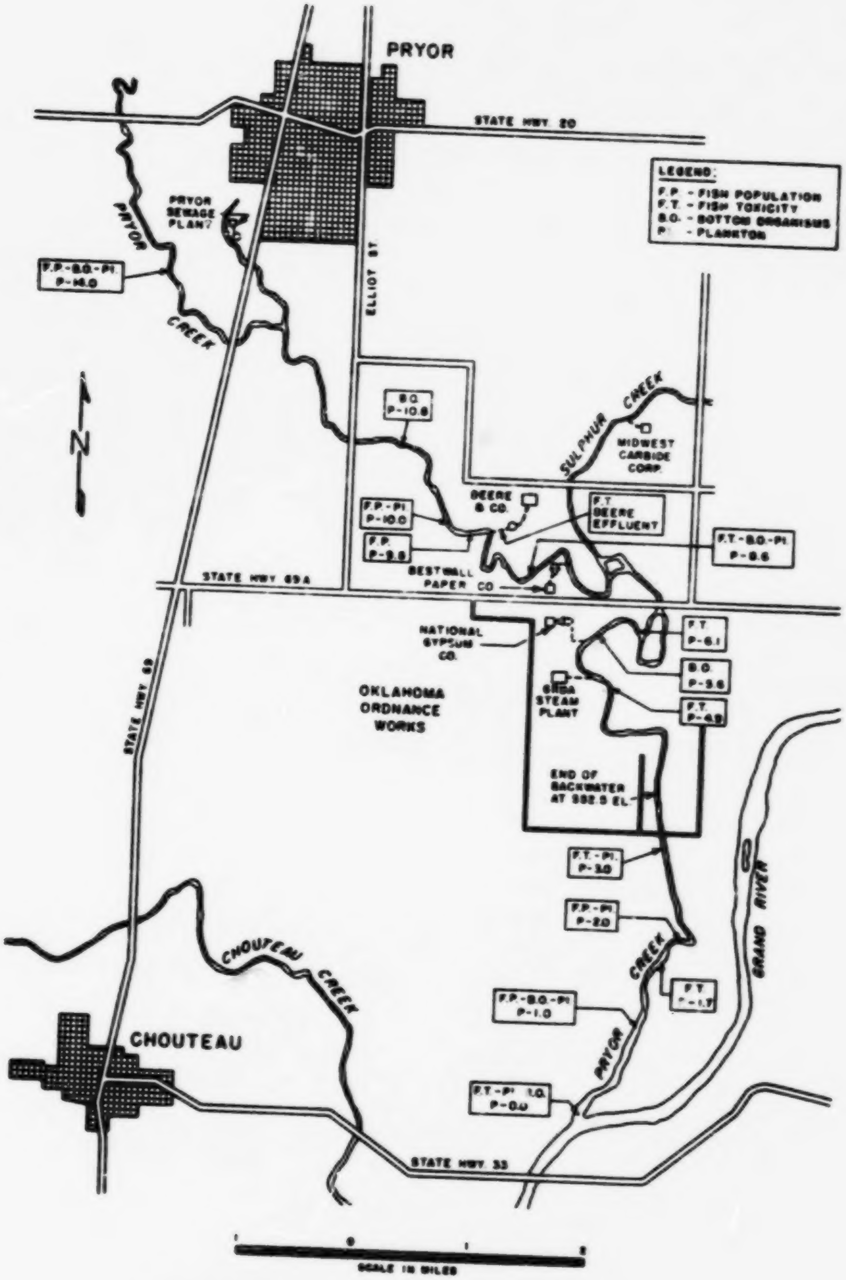
Determinations

Selection of determinations to be made was based on knowledge of the sources of wastes, and of their known and potential effects on water quality.

Results of chemical analyses that proved to be of most significance were those for temperature, dissolved oxygen, biochemical oxygen demand, ammonia and organic nitrogen, and hydrogen sulfide. Of the biological examinations those for toxicity of waste and creek samples were especially revealing.

All chemical, physical and bacteriological determinations made appear in the tabulations of results, Tables A-1 through A-76, Appendix A. All biological examinations made appear in the tables at the ends of the 4 sections of the complete biological report, Appendix B.

10-A


PRYOR
STATE HWY 20
LEGEND:
F.P. - FISH POPULATION
F.T. - FISH TOXICITY
B.O. - BOTTOM ORGANISMS
Pl - PLANKTON
PRYOR SEWAGE PLANT
PRYOR CREEK
F.P.-B.O.-Pl P-14.0
ELLIOT ST.
N
B.O. P-10.8
SULPHUR CREEK
MIDWEST CARBIDE CORP.
DEERE & CO.
F.T DEERE EFFLUENT
F.P.-Pl P-10.0
F.P. P-9.8
F.T.-B.O.-Pl P-8.6
BESTWALL PAPER CO
STATE HWY 69A
NATIONAL GYPSUM CO.
F.T. P-6.1
B.O. P-5.6
GRDA STEAM PLANT
F.T. P-4.9
OKLAHOMA ORDNANCE WORKS
STATE HWY 69
END OF BACKWATER AT 552.5 EL.
F.T.-Pl. P-3.0
F.P.-Pl P-2.0
GRAND RIVER
CHOUTEAU CREEK
F.T. P-1.7
F.P.-B.O.-Pl P-1.0
PRYOR CREEK
CHOUTEAU
F.T.-Pl I.O. P-0.0
STATE HWY 33
1 0 1 2
SCALE IN MILES

BIOLOGICAL SAMPLING POINTS
PRYOR CREEK AND VICINITY
FIGURE 5

Hydrological Data

Flows from all sources of waste entering Pryor Creek, with the exception of that from the GRDA steam plant, were measured by weirs appropriate to characteristics of discharge and channels through which they flowed. Flow from the steam plant was measured by current meter.

Stream flow at intermediate points in Pryor Creek during the study was assumed to be the sum of the averages of the measured waste discharges above that point. Discharges of the creek from just below the GRDA steam plant to the mouth were obtained from a special gaging station installed and operated by the U. S. Geological Survey.

Pryor Creek discharges at State Highway 69 bridge for several years previous to the study were obtained from the U. S. Geological Survey.

Cross sections of Pryor Creek were measured by sounding water depths at 500 foot intervals along the creek. Cross sections were correlated by accepted land survey methods. The field survey data were plotted and planimetered to obtain areas from which volumes of water in the various creek sections were computed. These volumes were used with data on creek discharges to calculate times of water travel.

Similar cross sections for Ft. Gibson Reservoir were plotted from contour maps furnished by the U. S. Corps of Engineers. Cross sectional areas were measured by planimetering. Times of water travel through the reservoir for various discharges of Grand River were computed from these data.

Discharges of Grand River at the upper end of Ft. Gibson Reservoir during the study were computed by the U. S. Geological Survey from records of stage at their Choteau gaging station.

Records of stream flow at the Langley gaging station, below Grand Lake O' the Cherokees, also were furnished by the U. S. Geological Survey.

Miscellaneous Information

Additional background information, not described specifically in foregoing sections, was obtained from numerous sources.

Federal, State, municipal and industrial representatives contributed freely to the mass of information collected. Some was abstracted from previous reports. Some was obtained from interested private citizens.

In fact, few stream pollution surveys have involved cooperation by so many organizations, agencies and individuals as this one. This fact reflects the widespread interest in the problem, and the desire of many to assist in its solution.

The Public Health Service Regional Office at Dallas undertook the assembly of the miscellaneous background information. In this endeavor it had full cooperation of other Federal and State agencies, and especially of the Oklahoma Department of Public Health.

PRESENTATION OF DATA

Laboratory Data

The data obtained by field and laboratory analyses of routine waste and stream samples are given in Table A-1 through A-76 of Appendix A. The tabulations include waste and stream flows for the days that samples were collected. They also include results of bacteriological examination.

Results are presented in both parts per million (ppm) and in pounds per day.

The results of biological examinations are incorporated in the several sections of the separate biological report which constitutes Appendix B.

Hydrological Data

All basic hydrological data are presented in Appendix D.

Volumes of various sections and times of water travel through the sections of Pryor Creek are given in Tables D-1 and D-2.

Records of stream flow in Pryor Creek are given in Table D-3.

Records of stream flow in Grand River near Langley and Choteau are given in Tables D-4 and D-5.

A chart showing times of water travel through Ft. Gibson Reservoir for various flows is included in Appendix D as Figure D-1.

Charts and Graphs

Much of the basic data is summarized and presented in tabular and graphic form. These tables and figures appear at appropriate points in the following section in which results are discussed.

DISCUSSION OF RESULTS

Sources of Wastes

Waste Flows

The average daily quantities of wastes discharged from the 5 waste sources are shown in the following tabulation.

Table 1

Waste Flows

	Discharge	
	MGD	%
Pryor Sewage Plant	0.44	9.8
Deere and Co.	0.15	3.3
Bestwall Co.	1.49	33.1
National Gypsum Co.	0.66	14.7
GRDA Plant	1.76	39.1
Total	4.50	

The GRDA steam plant waste stream contributed nearly 40 percent of the total waste discharged to Pryor Creek. As previously noted, however, the waste water from the steam plant was relatively clean and its effect on the creek tended to be beneficial rather than detrimental.

The Bestwall waste stream was the next largest of the discharges comprising one-third of the total. This was more than the combined discharge from the other 3 sources of pollutional wastes.

Nitrogen Compounds

The waste and stream samples were analyzed for ammonia, nitrites, nitrates, and organic nitrogen. The quantities of nitrites and nitrates in the wastes proved to be negligible. For this reason Table 2 presents the individual average daily quantities of only ammonia and organic nitrogen from the 5 waste sources. The slight differences between the sums of these 2 compounds and the corresponding totals represent the nitrites and nitrates. For example, the total of nitrogen compounds from all sources contained only 9 pounds per day of nitrite and nitrate nitrogen. In this table and elsewhere in the report, unless otherwise specified, the nitrogen compounds are given in terms of nitrogen (N) rather than the particular nitrogen compound involved.

Table 2

Sources of Nitrogen Compounds

	Nitrogen					
	Ammonia		Organic		Total	
	Lbs/day	%	Lbs/day	%	Lbs/day	%
Pryor Sewage Plant	12	0.3	17	0.5	34	0.4
Deere and Co.	3,730	98.1	3,570	96.8	7,301	97.3
Bestwall Co.	45	1.2	57	1.5	103	1.4
National Gypsum Co.	16	0.4	21	0.6	37	0.5
GRDA Plant	2	-	24	0.6	28	0.4
Totals	3,805		3,689		7,503	

The John Deere and Company wastes contributed a little more than 97 percent of all nitrogen compounds discharged to Pryor Creek. Of the 7,300 pounds per day of nitrogen in the Deere plant wastes about one-half was in the form of ammonia and the other half was organic nitrogen. The organic nitrogen was assumed to be urea.

Nitrogen in wastes from all other sources totaled 202 pounds per day.

Because of the known toxicity of ammonia to fish, a sample of the Deere plant waste lagoon effluent was used in controlled fish toxicity studies. The effluent sample contained about 2,500 ppm of ammonia nitrogen. This was nearly 500 ppm less than the average ammonia content of the 6 routine samples collected for chemical analysis during the study.

All test solutions of the sample containing 25 ppm of ammonia nitrogen (1 percent of sample) or more were toxic to nearly all of the exposed fish. A test solution containing 12.5 ppm of ammonia nitrogen was toxic to 20 percent of the test fish in 48 hours. These results are in satisfactory agreement with other findings of ammonia toxicity at moderate pH values.

Oxygen Demand

The usual 5 day 20°C biochemical oxygen demand (B.O.D.) was determined on the samples collected for chemical analysis. In addition, 10, 20 and 30 day B.O.D.'s were determined on a majority of the samples. The purpose of the longer test periods was to evaluate the effect of the nitrogen compounds on the ultimate B.O.D.

The average daily quantities of 5 and 30 day B.O.D. contributed by the 5 sources of wastes are shown below.

Table 3

Sources of Oxygen Demand

	B.O.D.			
	5 day		30 day	
	Lbs/day	%	Lbs/day	%
Pryor Sewage Plant	54	0.8	150(1)	0.9
Deere and Co.	60	0.9	> 705	4.3
Bestwall Co.	5,040	71.5	11,260	68.5
National Gypsum Co.	1,860	26.4	4,250	25.8
GRDA Plant	28	0.4	88	0.5
Totals	7,042		16,453	

(1) Estimated

The 2 paper mills contributed 97.9 percent of the 5 day B.O.D., of which a little less than three-fourths was from the Bestwall plant and a little more than one-fourth was from the National Gypsum plant. The data indicate that the 2 paper mills contributed 94.3 percent of the 30 day B.O.D. This percentage may be misleading. The average 30 day B.O.D. of the Deere waste is based on 5 results, of which 3 were indeterminate and are shown in Table A-13 as "equal to or greater than" the reported values. The 3 values were indeterminate because of total depletion of oxygen in the bottles that were incubated for 30 days. If dilutions of the samples for 30 day B.O.D. had been sufficient to assure measurable oxygen at the end of 30 days the indeterminate values probably would have been considerably higher than reported. A theoretical computation, based on the average ammonia and urea content of the Deere effluent samples and the assumption that these compounds oxidized completely indicates that the ultimate B.O.D. of the Deere waste could have been 27,050 ppm, equivalent to 33,360 pounds per day.

Organic Solids

The organic solids contained in the wastes are indicated by the results of volatile solids determinations. Average daily quantities of total, suspended and dissolved volatile solids from the 5 sources of wastes are shown below.

Table 4

Sources of Organic Solids

	Volatile Solids					
	Total		Suspended		Dissolved	
	Lbs/day	%	Lbs/day	%	Lbs/day	%
Pryor Sewage Plant	500	1.7	133	6.8	367	1.3
Deere and Co.	14,000	47.2	184	9.5	13,816	49.8
Bestwall Co.	10,100	34.0	1,080	55.5	9,020	32.6
National Gypsum Co.	3,700	12.5	138	7.1	3,562	12.8
GRDA Plant	1,380	4.6	410	21.1	970	3.5
Totals	29,680		1,945		27,735	

The Deere plant contributed nearly one-half of the total volatile solids, the Bestwall plant about one-third, and the National Gypsum plant about one-eighth. Relative contributions of dissolved volatile solids were quite similar. Although there is no direct quantitative correlation between volatile solids and B.O.D., the volatile solids results indicate in a general way that the Deere plant waste might be expected to contribute an important portion of the ultimate B.O.D. This lends support to the theoretical calculation of B.O.D. based on nitrogen content of the Deere wastes discussed in the above sections on nitrogen compounds and oxygen demand.

The Bestwall plant contributed over one-half of the suspended volatile solids. This probably was principally wood fiber which was lost from the process, and could settle in the creek to form putrescible sludge banks. Sludge deposits were observed in the creek in the vicinity of the point where Bestwall plant waste discharged.

Both paper mills had relatively low fiber losses by comparison with losses found at other paper mills. Fiber losses from Bestwall were 0.5 percent, based on finished product, and National Gypsum losses were only 0.2 percent.

Alkalinity and pH

The quantities of alkalinity contributed by the 5 sources of waste are given in the following table.

Table 5

Sources of Alkalinity

	Alkalinity			
	Phenolphthalein		Total	
	Lbs/day	%	Lbs/day	%
Pryor Sewage Plant	-(1)	-	516	6.5
Deere and Co.	252	42.7	5,170	65.6
Bestwall Co.	0	0	275	3.5
National Gypsum Co.	0	0	154	2.0
GRDA Plant	338	57.3	1,760	22.4
Totals	590		7,875	

(1) Not Determined

The Deere plant and the GRDA steam plant were major contributors of alkalinity, with the Deere plant waste accounting for two-thirds of the total. Both the sodium hydroxide used in the Deere manufacturing process and the ammonia produced are alkaline materials. The GRDA steam plant alkalinity concentration was about 20 ppm higher than that of the Ft. Gibson Reservoir water pumped to the steam plant from above Pryor Creek. The alkaline material added at the steam plant which accounted for this small increase was not determined during the survey.

The wastes from both plants contained phenolphthalein alkalinity. The portions of the total alkalinities represented by the phenolphthalein alkalinities were small. This fact indicated that bicarbonates and small quantities of carbonates accounted for most of the alkalinities.

Table 6 presents the average pH of the wastes. Included is the range in pH values of all individual sample portions collected, with the exception of those at the sewage plant. The range in values for the sewage plant is for the daily composite samples.

Table 6

pH of Wastes

	pH	
	Average	Range
Pryor Sewage Plant	8.6	8.5 - 8.7
Deere and Co.	8.2	7.8 - 8.5
Bestwall Co.	4.8	4.4 - 5.1
National Gypsum Co.	5.7	5.0 - 6.5
GRDA Plant	9.5	9.1 - 10.0

The GRDA steam plant waste stream exhibited the highest pH values. The possible significance of this is increased by the fact that discharge of this waste was greatest of the 5 sources, with 1.76 million gallons per day (mgd) compared to 0.44 mgd for the sewage plant and only 0.15 mgd for the Deere plant. The low pH values for the 2 paper mill waste streams probably resulted from the use of alum in the manufacturing processes.

Pryor Creek

Hydrology

The 269 square mile drainage area of Pryor Creek produced no run-off in the vicinity of Pryor during the survey. The fact that this was not an unusual condition is shown by the flow duration curve for Pryor Creek in Figure 6. This curve was prepered from stream flow data for the years 1953-1956 in Table D-3 of Appendix D.

During that period there was no natural flow in Pryor Creek for 42.8 percent of the time and flow was less than 1 cfs 67.5 percent of the time. Flows varied through the range of 0 to 4,000 cfs during the 3 years.

Flow in the creek during the survey consisted of wastes from the 5 sources previously discussed, starting with the effluent of the Pryor sewage treatment plant lagoon. The cumulative flows, based on measurements of individual waste flows, are given in the following table.

Table 7

Flow in Pryor Creek

	Mile	Flow MGD	Flow CFS
Pryor Sewage	13.5	0.44	0.68
Deere Plant Waste	9.5	0.59	0.91
Bestwall Plant Waste	8.0	2.08	3.22
National Gypsum Plant Waste	5.5	2.74	4.25
GRDA Steam Plant Waste	5.2	4.50	6.97

As noted previously, the flow in Pryor Creek during September was taken from U. S. Geological Survey gaging records below the GRDA steam plant. The average discharge below the steam plant was 4.14 mgd (6.4 cfs) instead of the 4.50 mgd based on measurement of all wastes at their sources.

For most of the distance from mile 13.5 to mile 3.4 the creek is a series of pools and riffles. From mile 3.4 to its mouth the creek is ponded by backwater from Ft. Gibson Reservoir.

The volume of water in the creek was determined from mile 10.5 to the mouth of the creek. The total volume was 104.5 million gallons. Volumes of sections between pertinent points are given in Table D-1 of Appendix D.

Times of water travel through pertinent sections are given in Table D-2 of Appendix D. Theoretical time of water travel from mile 10.5 to the mouth of the creek, based on total displacement, was 54.3 days. About three-quarters of this time was required for passage through the pool and riffle section and about one-quarter for passage through the backwater section.

Water from Ft. Gibson Reservoir intruded various distances upstream on the surface of Pryor Creek backwater during the survey. The upper limit of the intruded water varied from about 0.5 to 1.5 miles above the mouth of the creek and averaged about 1 mile.

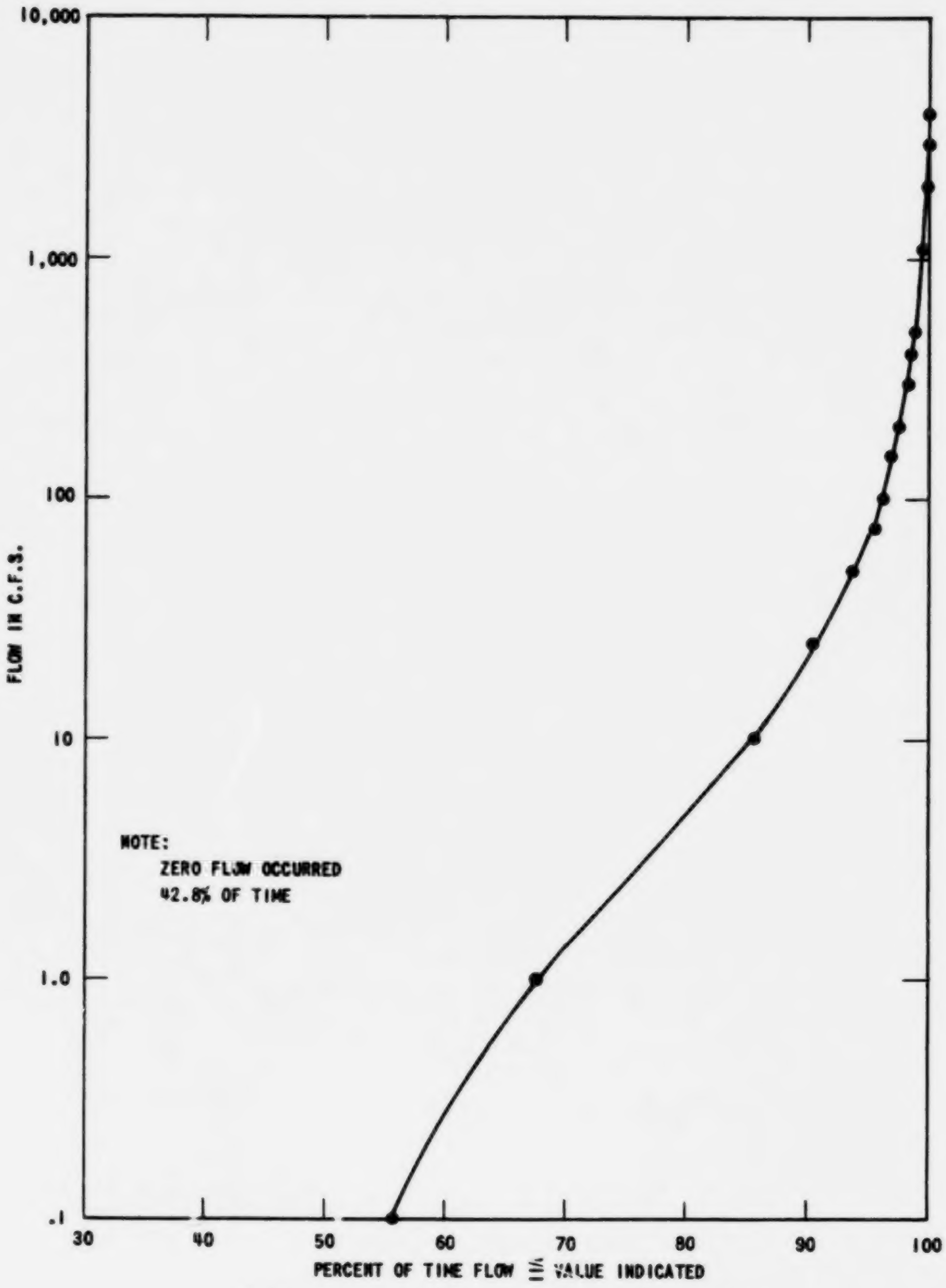
An example of this intrusion is illustrated by the results of conductivity measurements in Figure 7. Because of the intrusion results of sampling at the 6 foot depth at the mouth of the creek, station P-0.0, represented mixtures of creek and reservoir water. Results on samples taken at the 12 foot depth at P-0.0, however, appear to be reasonably representative of Pryor Creek water, and only the results at this depth are used in the discussion and interpretation of the data.

Nitrogen Compounds

Figures 8 through 10 show average quantities of nitrogen compounds, in pounds per day, passing various points on Pryor Creek.

The total nitrogen curve, Figure 8, shows the major rise in nitrogen compounds at the point where the Deere plant waste enters the creek. Below this point there was a sharp drop in the 3.2 miles downstream to station P-6.4. In this distance, which the creek required about 29 days to traverse, there was an 88.5 percent reduction in total nitrogen. From P-6.4 to P-0.0 there was a decrease of 72.6 percent in 19 days time of water travel. The total reduction between mile 9.6 and P-0.0 was 96.4 percent in about 48 days. Comparable reduction in ammonia nitrogen was 95.3 percent.

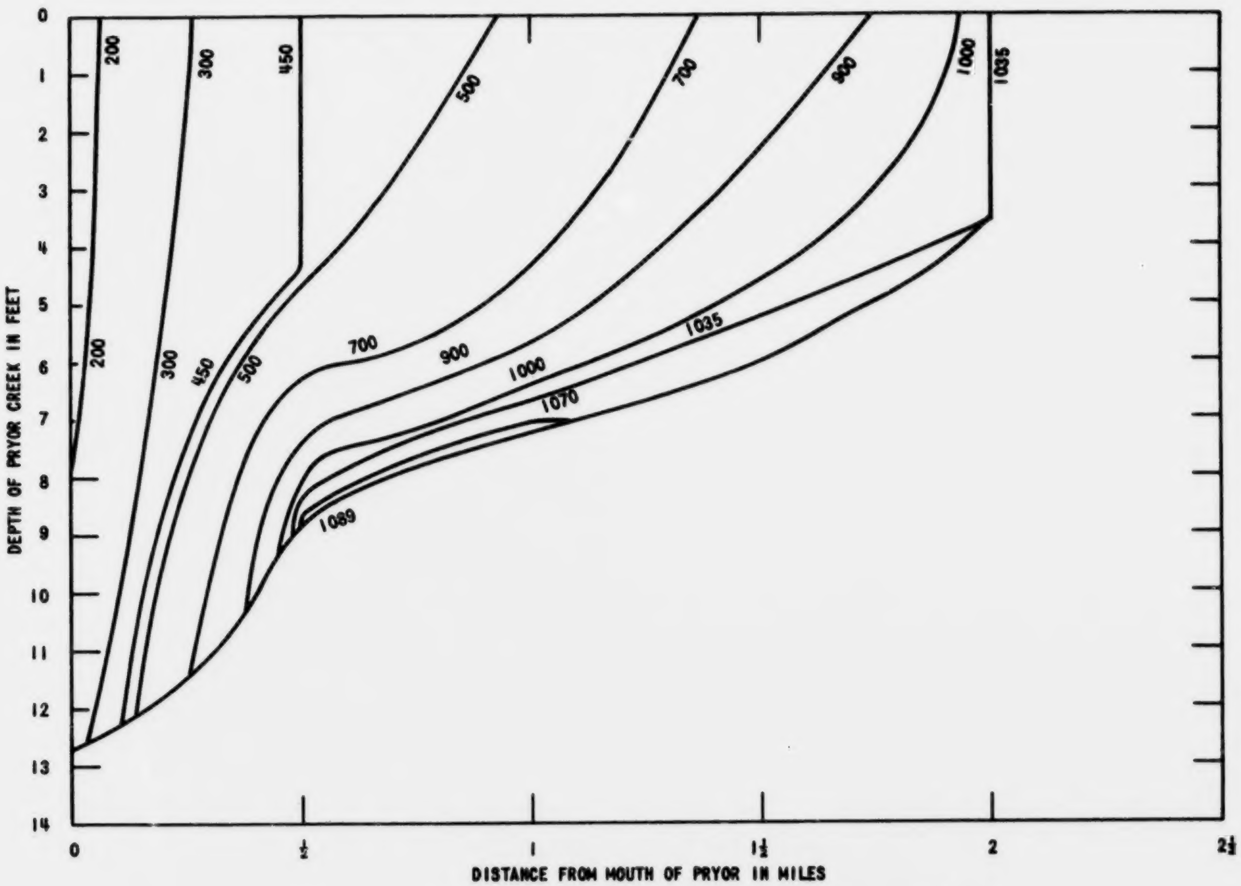
There are several physical and biological means which can account for loss of nitrogen compounds from the creek water. At the upper end of the section where ammonia concentrations and pH were high, there was loss of ammonia by direct escape to the atmosphere. The odor of ammonia frequently was observed in the area. Approximately one-half



FLOW - DURATION OF PRYOR CREEK, PRYOR, OKLA.

JAN. 1953 THRU DEC. 1956

FIGURE 6

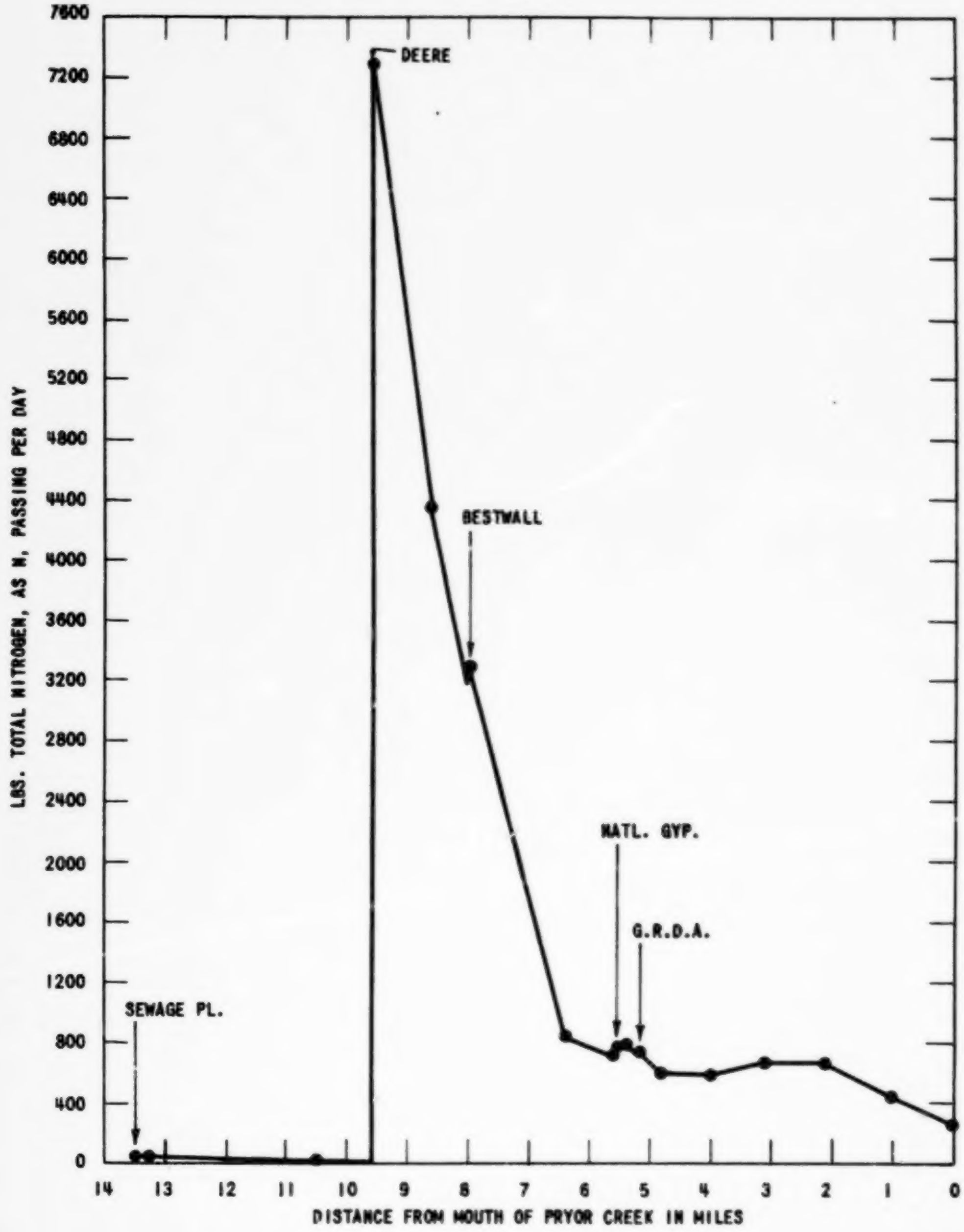


SPECIFIC CONDUCTIVITY IN MHOS/CM. IN BACKWATER OF PRYOR CREEK

9/12/56

PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 7

20-C



QUANTITY OF TOTAL NITROGEN PASSING SAMPLING STATIONS

PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 8

of the nitrogen was in the form of urea when it left the Deere waste lagoon and at least a portion of it was converted to ammonia by biological action. This conversion is indicated by the sharp drop in organic nitrogen between mile 9.6 and P-8.6 (Figure 10) and by the rise in ammonia nitrogen in this section (Figure 9). Both ammonia and urea probably were metabolized and stored in the bodies of aquatic organisms which died and settled to the bottom of the creek. This action probably was especially effective in the large pool, above P-8.6, into which the Deere waste discharged. This pool was bright green with prolific growths of algae, nourished by the nitrogen content of the waste. From P-5.6 to the mouth of the creek the water contained hydrogen sulfide. This compound reacts with ammonia to yield ammonium sulfhydrate, which is more volatile than ammonia and therefore can escape more readily to the atmosphere.

At the 12 foot depth at P-0.0, which is taken to represent the waste load entering Ft. Gibson Reservoir, there remained 251 pounds per day of total nitrogen, which included 194 pounds per day of ammonia nitrogen.

Oxygen Demand

The average 5 and 30 day B.O.D.'s found in Pryor Creek are shown in Figures 11 and 12. The major contributors of oxygen demanding materials are indicated to be the Bestwall and National Gypsum paper plants.

Both the 5 and the 30 day B.O.D. curves exhibit puzzling rises between mile 8.0, immediately following allowance for the B.O.D. contributed by Bestwall waste, and P-6.4. No waste is known to enter the creek between these 2 points to account for the apparent increases. Only 3 samples were collected at P-6.4, compared to 7 at stations above and below P-6.4. However, the B.O.D. results obtained on the 3 samples were sufficiently consistent to justify reasonable confidence that the average of the 3 values was not abnormally high.

It is believed that this apparent anomaly is further evidence of the unresolved relationship between nitrogen compounds and oxygen demand previously discussed in the section on B.O.D. of the sources of waste. If the potential oxygen demand of the nitrogen compounds in the Deere waste had been exhibited at mile 9.6, where the waste entered, and if the potential demand of the nitrogen compounds found by sampling at P-8.6 had been exerted, the 30 day B.O.D. curve for Pryor Creek would have been as shown by Figure 13. The shape of this theoretical curve appears to be more logical than the 30 day B.O.D. curve based only on creek and wastes sample results (Figure 12).

It is recognized, however, that the potential oxygen demand of the nitrogen waste probably did not deplete the oxygen resources of the creek water. The probable means by which at least a portion of the nitrogen compounds were eliminated from the creek water have been discussed previously. Further evidence that the compounds depleted little if any of the creek's oxygen resources is the fact that only 1.1 pounds per day of nitrate nitrogen were found at P-0.0. If the nitrogen compounds had depleted appreciable quantities of the creek's oxygen resources the resulting nitrates should have been found on analysis. While the unresolved relationship of the nitrogen compounds and oxygen demand is technically irritating it is not practically important in evaluation of the condition of the creek.

Between P-6.4, the station at which maximum B.O.D. was found, and P-0.0 the reduction in 30 day B.O.D. was 86.3 percent in 19 days. Corresponding reduction in 5 day B.O.D. was 91.1 percent.

Dissolved Oxygen

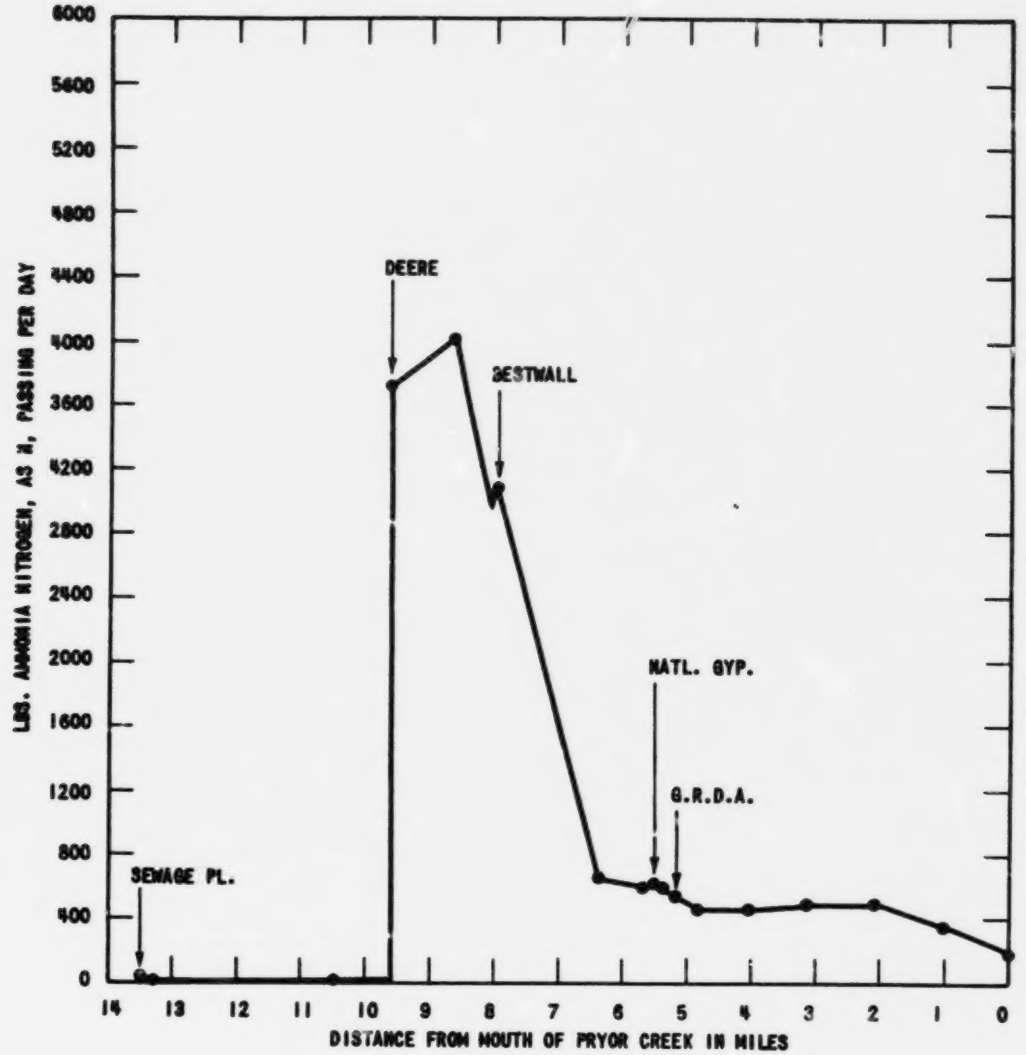
Pryor Creek water was devoid of dissolved oxygen (D.O.) from just below the "low water bridge" (P-8.6) to its mouth. Just below the Pryor sewage treatment plant the observed D.O. averaged 5.1 ppm and ranged between 3.6 and 6.6 ppm. At P-10.5, above the Deere plant, the D.O. averaged 4.3 ppm and ranged between 3.7 and 5.6 ppm. At P-8.6, just above the low water bridge and at the extreme downstream end of the pool into which the Deere plant waste discharged, the D.O. averaged 3.3 ppm and ranged between 0.0 and 7.0 ppm.

There was evidence that photosynthesis by algae was a factor in the D.O. results obtained at the 3 above stations. Most of the samples were collected relatively early in the morning, before photosynthesis was most effective. In general, the earlier in the morning that samples were collected the lower were the D.O. values found. It is probable that D.O. was quite low at all of them during the nights. In fact the D.O. was 0.0 as late as 7:40 AM on 2 days at P-8.6, but was as high as 7.0 ppm by 9:05 AM, which was the latest time that any sample was collected at this station.

It is quite probable that water at all of these stations would have been supersaturated with D.O. during the afternoons.

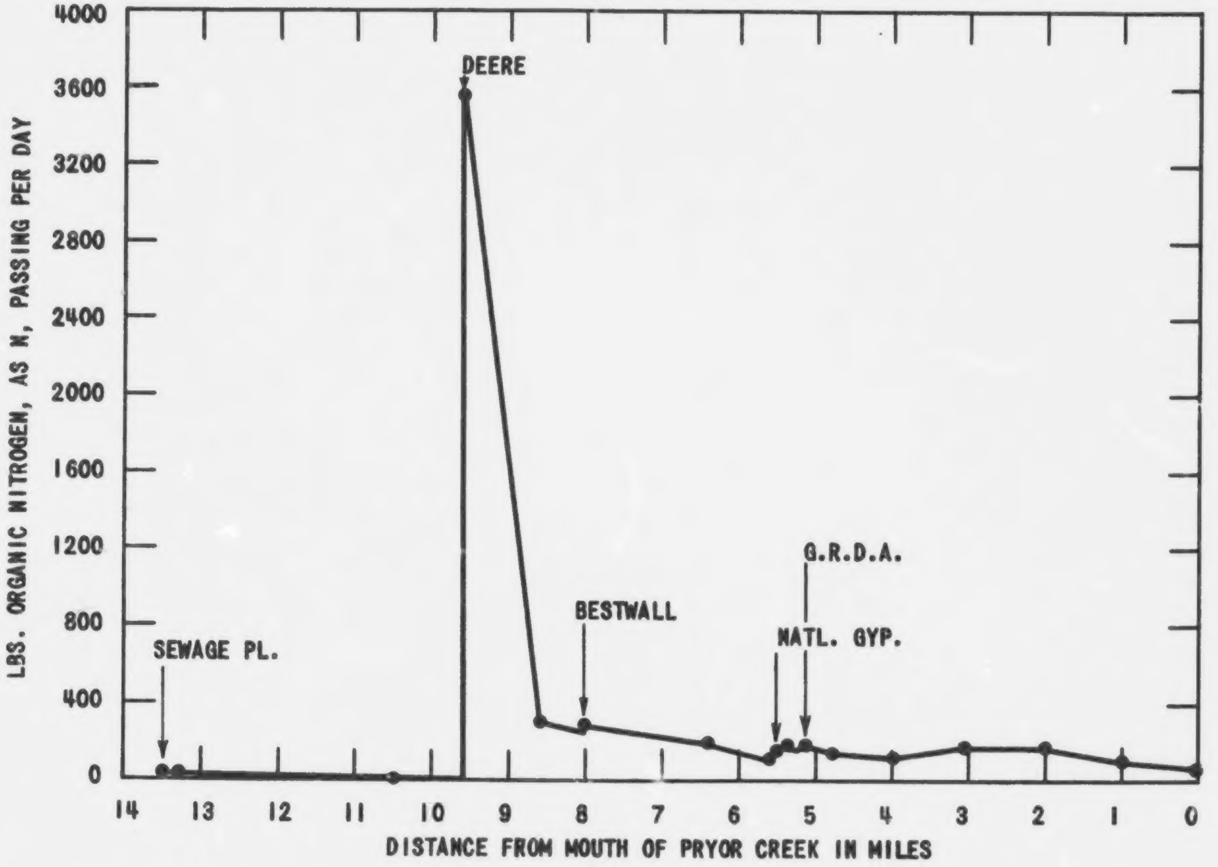
Samples were collected at 2 depths at the mouth of the creek. Only 2 of 6 samples collected near the bottom contained D.O. One had 1.0 ppm and the other 6.8 ppm of D.O. The average of all samples was 1.3 ppm. The 2 samples containing D.O. undoubtedly reflected the effects of intrusion of water from the reservoir, rather than unmixed Pryor Creek water. All samples collected at the 6 foot depth contained some D.O., with a range of 0.15 to 6.1 ppm, and an average of 4.7 ppm. Obviously water at the 6 foot depth included much reservoir water, since no D.O. was found at station P-1.0.

22-A



QUANTITY OF AMMONIA PASSING SAMPLING STATIONS

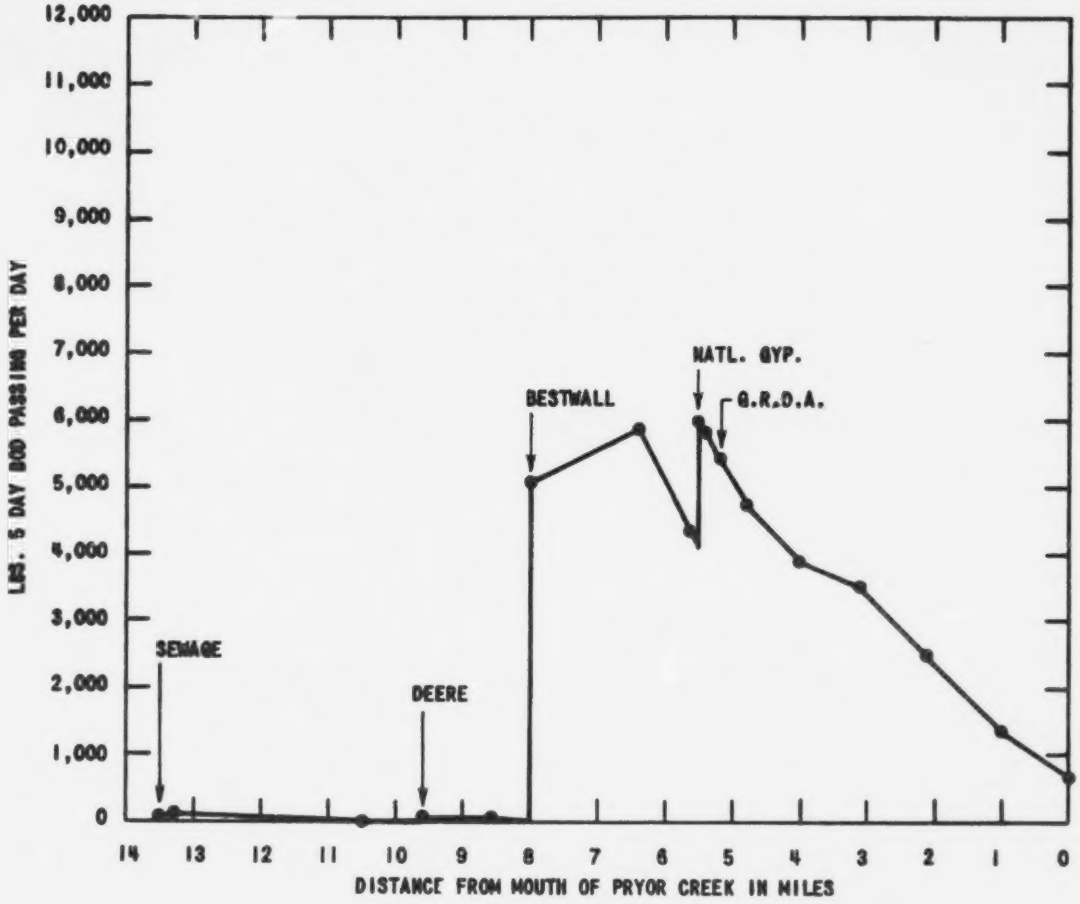
PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 9



QUANTITY OF ORGANIC NITROGEN PASSING SAMPLING STATIONS

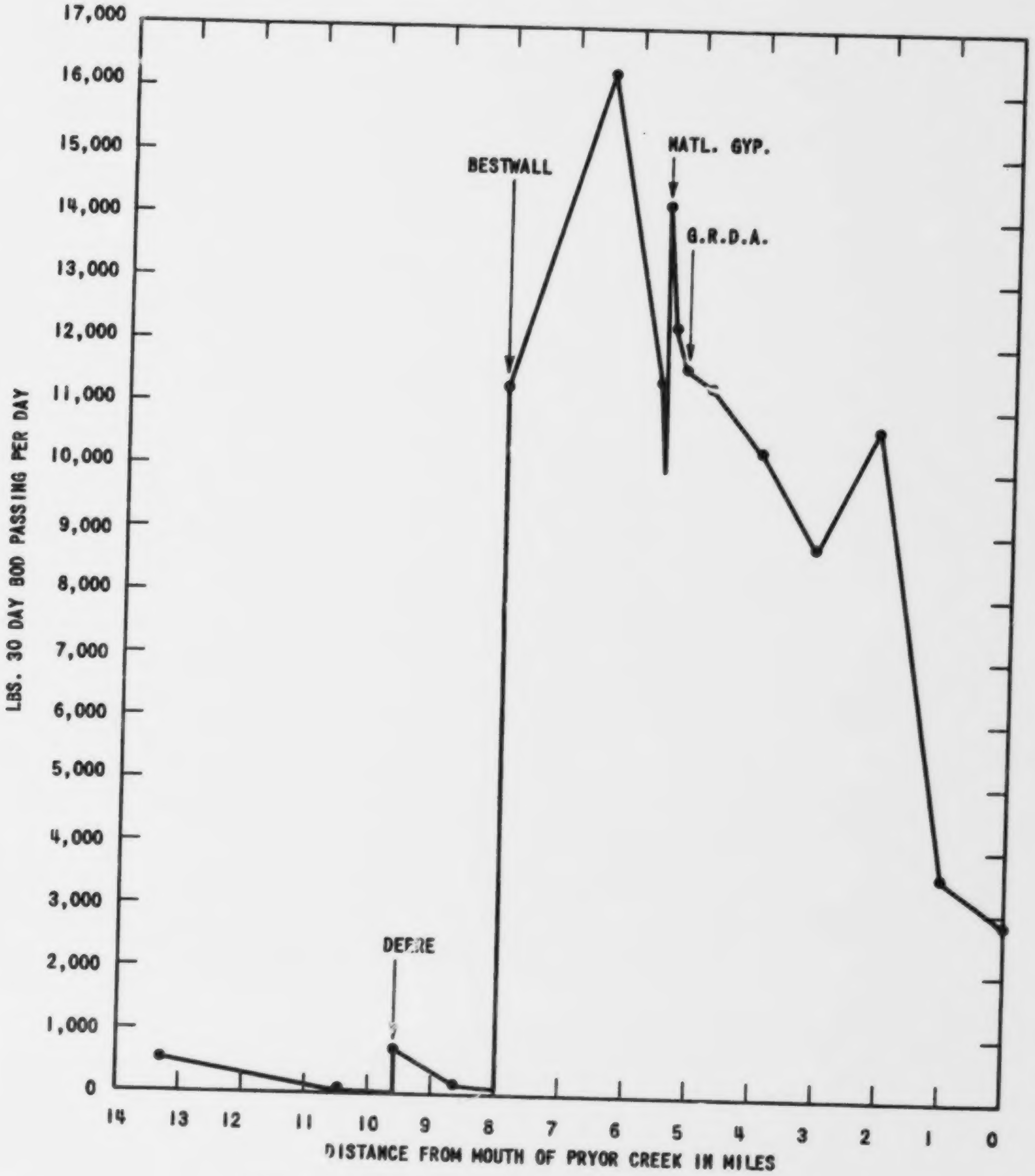
PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 10

22-e



QUANTITY OF 5 DAY BOD PASSING SAMPLING STATIONS

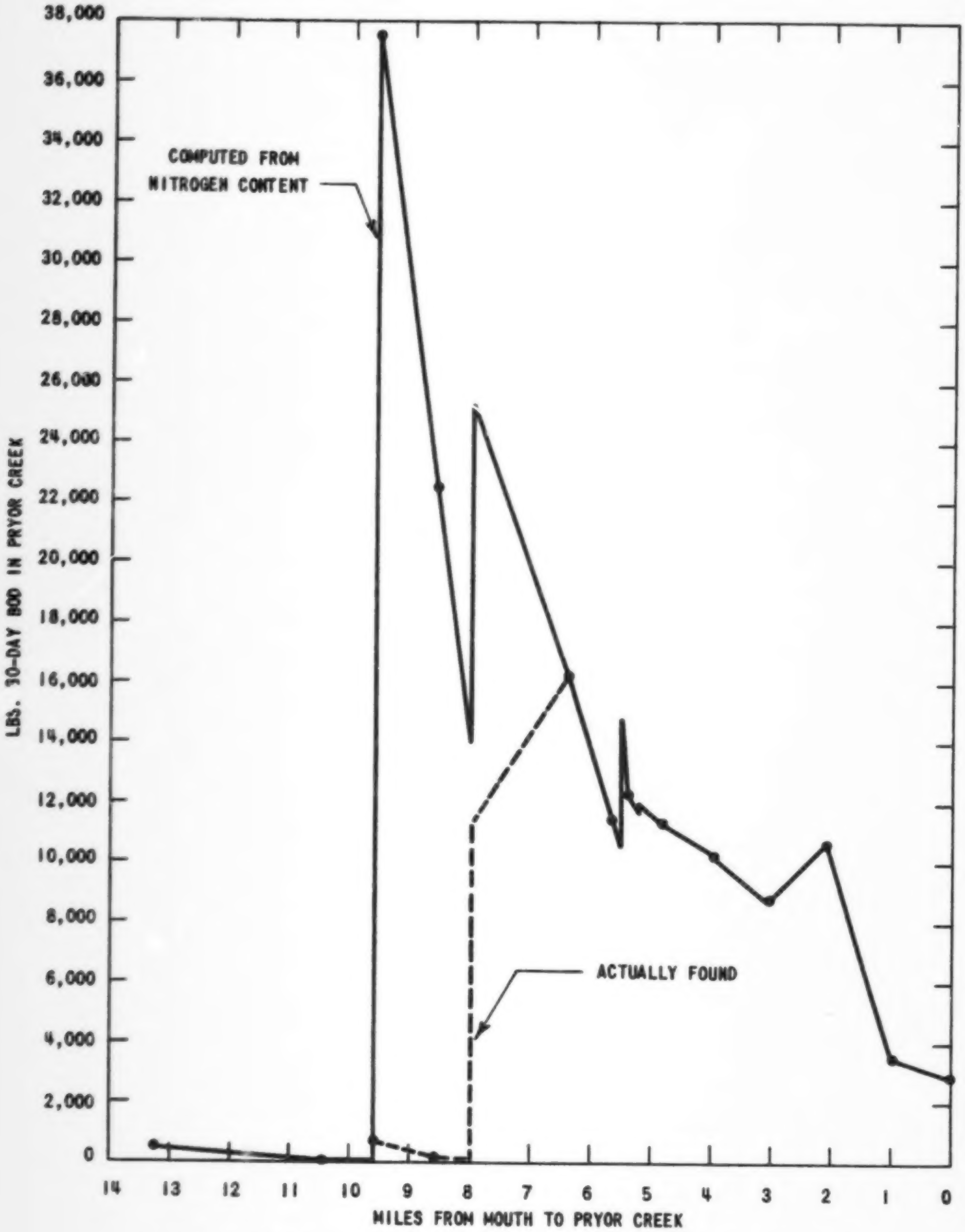
PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 11



QUANTITY OF 30 DAY BOD PASSING SAMPLING STATIONS

PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 12

22-E



QUANTITY OF 30-DAY BOD PASSING SAMPLING STATIONS WITH VALUES FROM MILE 9.0 TO 8.0 COMPUTED FROM NITRIGEN CONTENT OF WATER
PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 13

Organic Solids

Total, dissolved, and suspended volatile solids data for Pryor Creek are shown graphically in Figures 14 through 16.

Both the total and dissolved volatile solids curves (Figures 14 and 15) follow in a general way the combined theoretical and observed 30 day B.O.D. curve of Figure 13. While there is not a direct correlation, as previously noted, between these 2 factors the similarity in trends gives additional support to the theoretical aspects of Figure 13.

The reduction in dissolved volatile solids between mile 9.6, immediately following the entrance of Deere waste, and P-0.0 is 87.9 percent in about 48 days.

The suspended volatile solids curve (Figure 16) reflects the effects of the fibers lost from the paper plants. If the point for P-4.8, which appears to be inconsistent with other points, be ignored the curve indicates a minimum of settling of suspended volatile matter. This suggests that organic sludge deposits in the creek probably were quite minor. Except for localized deposits around the 2 points of paper plant waste discharges no evidences of heavy sludge deposits were noted during the survey.

Alkalinity and pH

The wastes in Pryor Creek combined to yield a mixture below the GRDA steam plant with moderate average alkalinities in the range of 208 to 338 ppm. The average pH in this section ranged between 7.2 and 7.6.

Below the Deere plant total alkalinities were rather high, with an average of 1,493 ppm at P-8.6. This included an average of 46 ppm of phenolphthalein alkalinity. The pH was moderately, but not excessively, high, averaging 8.4. Downstream the mildly acid paper mill wastes reduced both alkalinity and pH to the values cited in the preceding paragraph.

Hydrogen Sulfide

No hydrogen sulfide was discharged in the waste from any of the 5 sources. Hydrogen sulfide commonly is formed in streams containing sufficient oxygen demanding materials to cause total depletion of D.O. The organisms responsible for anaerobic decomposition extract their required oxygen from the sulfates of the water. Pryor Creek contained sulfates from natural sources, from the sulfuric acid used to neutralize excess sodium hydroxide in the Deere waste lagoon, and from alum (aluminum sulfate) used in the paper manufacturing processes at both the Bestwall and the National Gypsum plants.

The accurate determination of hydrogen sulfide in a stream can be performed only in the field on samples collected with care to avoid aeration. The analytical procedure is too involved and time consuming to permit field use during the routine collection of samples for chemical analysis.

For these reasons determination of hydrogen sulfide was limited to 2 sets of samples during the survey. All of these determinations were made by the chemist in charge of the trailer laboratories.

Figure 17 shows the average hydrogen sulfide, in pounds per day, in Pryor Creek. None was found at P-10.5 or P-8.6, where D.O. usually was present during daylight hours. As previously noted, P-8.6 was in the downstream end of the pool into which Deere waste discharged, and was just above the low water bridge. The culvert under this bridge separated this pool from the next one downstream, into which Bestwall waste discharged. Effects of Bestwall waste were obvious immediately below the bridge, even though this was 0.6 miles above the point of waste discharge.

Hydrogen sulfide in the range of 136 to 295 pounds per day was found at stations P-5.6, P-5.4 and P-4.8. Below P-4.8 the sulfide rose to a peak of 1,900 pounds per day at P-3.1 and then dropped to a little less than 700 pounds per day at the mouth of the creek.

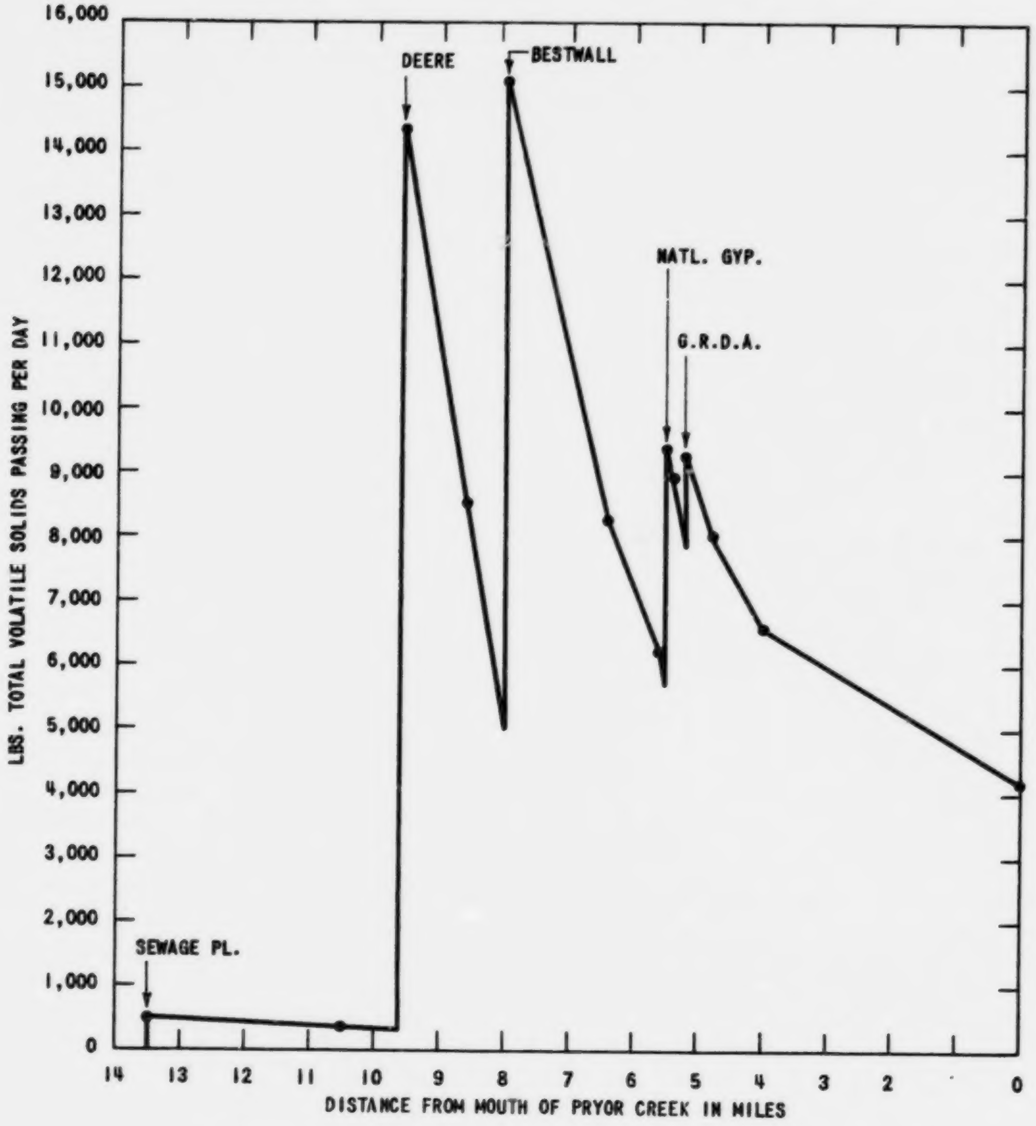
The organic matter in the wastes of the Bestwall and National Gypsum plants was principally responsible for the depletion of D.O. in this section of Pryor Creek. This depletion permitted anaerobic decomposition and the production of hydrogen sulfide. If ammonia had served as an acceptor of oxygen from sulfates to produce hydrogen sulfide nitrates should have resulted and should have appeared in the creek water. As has previously been noted, the nitrates found were negligible.

Miscellaneous Analytical Data

Color and chlorides were determined routinely on most samples, but failed to reveal anything of especial significance.

A few special determinations were made for oils, phenols, cyanides and chromium. The results did not reveal these materials in quantities sufficient to be harmful.

24-A

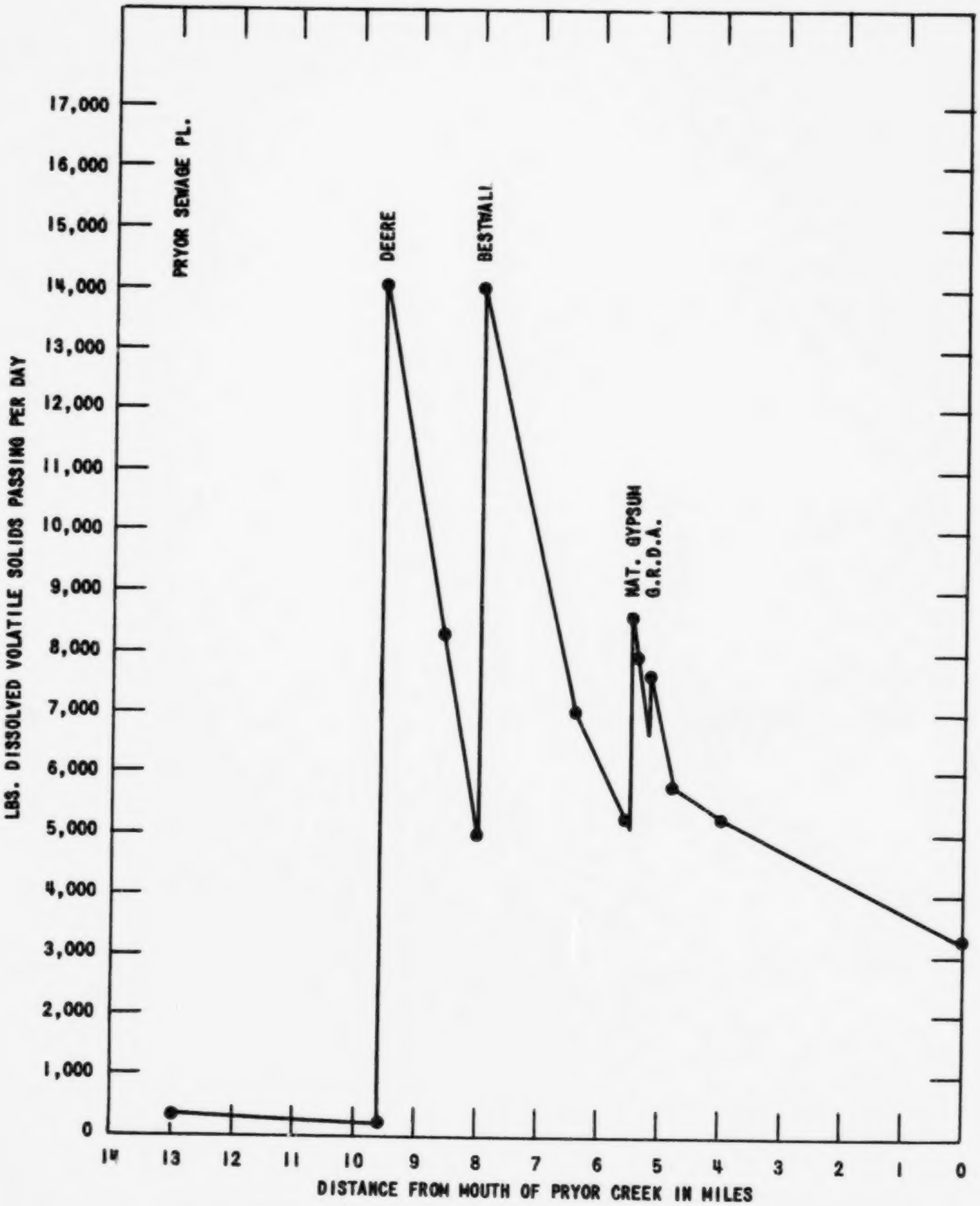


QUANTITY OF TOTAL VOLATILE SOLIDS PASSING SAMPLING STATIONS

PRYOR CREEK - FORT GIBSON LAKE SURVEY

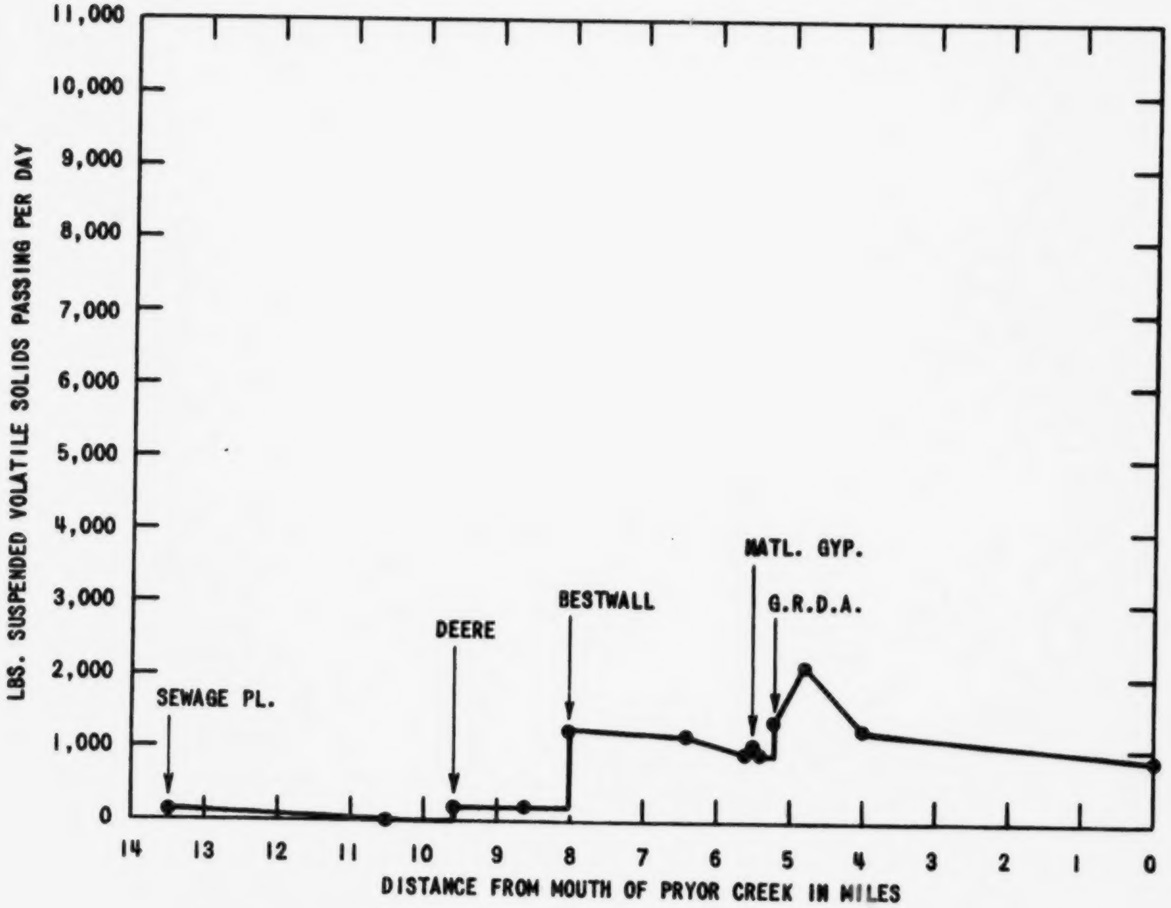
FIGURE 14

24-B



PRYOR CREEK - FORT GIBSON LAKE QUANTITY OF DISSOLVED VOLATILE SOLIDS PASSING SAMPLING STATIONS

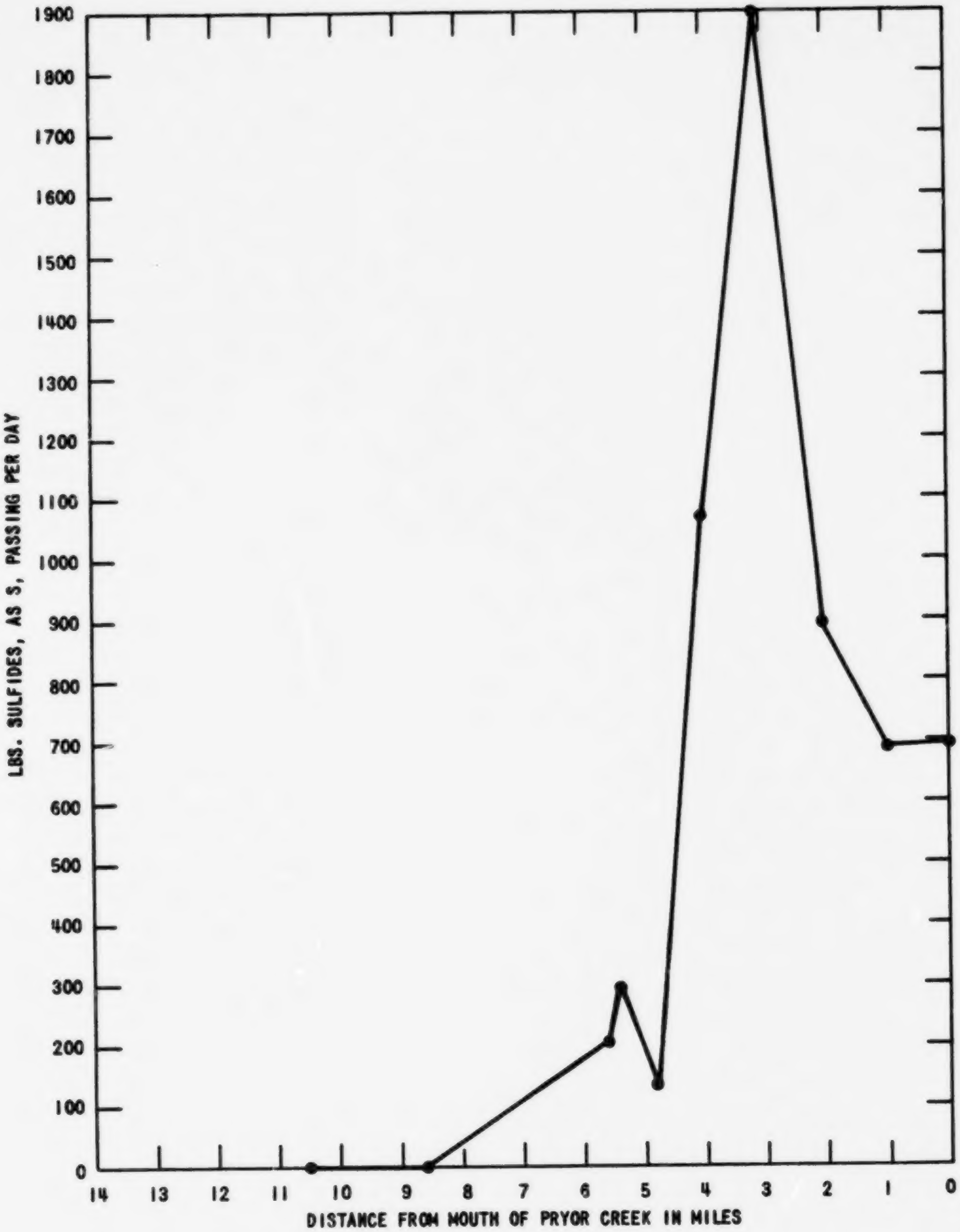
Figure 15



QUANTITY OF SUSPENDED VOLATILE SOLIDS PASSING SAMPLING STATIONS

PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 16

24-D



QUANTITY OF SULFIDES PASSING SAMPLING STATIONS

PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 17

Reproduced from best available copy.

Accumulation of Wastes in Pryor Creek

The total quantities of waste constituents that accumulate in Pryor Creek during dry weather are many times as great as quantities discharged to the creek daily. It is the large accumulation of wastes and their products of decomposition that cause sudden damage when flushed rapidly into Ft. Gibson Reservoir by a quick rise in Pryor Creek. In order to compute the accumulated quantities of these materials average concentrations first were computed for the midpoint of each longitudinal stream section. These midpoint averages were obtained from the concentrations found at the two ends of the section. The midpoint averages then were combined with the volume of water in the section to compute the total weights of materials in the section. The sums of the weights in all sections gave the total weights for the entire creek which are presented in the following table.

Table 8

Accumulated Constituents in Pryor Creek

Material	Added Lbs/day	Accumulated Total Lbs.	Accumulation Factor
Total Nitrogen	7,503	133,500	17.8
Ammonia Nitrogen	3,805	100,400	26.4
Organic Nitrogen	3,689	33,000	8.9
5 Day B.O.D.	7,042	92,700	13.2
30 Day B.O.D.	16,453	254,000	15.4
Sulfides	--	13,000	--

The total nitrogen and the 5 and 30 day B.O.D.'s showed accumulations within a rather narrow range of about 13 to 18 times the daily amounts of waste constituents discharged to the creek. The relative low accumulation factor for organic nitrogen and the relative high factor for ammonia probably reflect the conversion of urea to ammonia in the creek. A "rule of thumb," or empirical figure of about 15 times the daily quantity discharged might be used to estimate total accumulations of similar constituents if discharged to the creek at rates other than those found during the survey.

Another convenient empirical figure is that 1 pound of hydrogen sulfide accumulated in the creek for each 0.54 pounds of 5 day B.O.D. discharged to the creek daily.

Both of these empirical relationships would be changed if the points at which the wastes discharge should be shifted up or down the creek.

Fish Populations

Fish populations were examined at 5 locations on Pryor Creek. The fish in the selected areas were killed by application of Pro-Noxfish. Fish were collected as they came to the surface. Any dead fish that floated to the surface by the following day also were collected. Fish were identified, counted, measured and weighed.

Detailed discussion of the findings are given in Appendix B. The fish collected are listed in Tables B-1 and B-2.

The farthest upstream station was in a pool of standing water in the Pryor Creek stream bed at P-14.0 (Figure 5). Since the creek was not flowing at this point there was no inflow to or outflow from the pool. In this pool 320 fish representing more than 12 species of both sport and rough fish were collected. These included a 19 inch channel cat, a 16.5 inch carp, an 8.6 inch crappie and a 10.9 inch bass. In addition several species of minnows were obtained.

The next station downstream, P-10.0, was below the Pryor sewage treatment plant, and above the point of discharge of the Deere plant wastes. More than 7 species of sport and rough fish were among the 258 fish collected here, as well as miscellaneous small fish. Here the fish were somewhat smaller, the largest being a 7.4 inch bass and a 6.3 inch crappie.

The third station, P-9.8, was near the upper end of the pool into which the Deere plant wastes discharge. The odor of ammonia at this point indicated that the Deere wastes had traveled upstream for nearly a quarter of a mile in the relatively quiet pool. No fish were found here.

No fish were found at P-2.0, below all sources of wastes and in the backwater portion of the creek.

At P-1.0 thousands of young shad, a few adult shad, 2 blue gills and 1 carp were collected. These apparently were in the surface water which had intruded from the lake, and did not reflect the quality of the polluted creek water which was passing underneath the surface layer.

The fish collected at the 5 points show that the creek above all sources of pollution and also below the Pryor sewage treatment plant supports a variety of desirable game fish. Starting at P-9.8, the farthest upstream point affected by industrial wastes, and extending to the mouth of the creek no fish life was present in the polluted water of the creek because of the industrial waste pollution.

Fish Toxicity

Samples of Pryor Creek water collected from several points in the section affected by industrial pollution were tested for toxicity to fish. Minimum concentrations of the creek samples that would kill the test fish were determined by observing fish placed in several different concentrations of each creek sample mixed with Pryor city water. Carefully controlled testing conditions were maintained in accordance with recognized procedures for such tests. Especially careful handling of samples to avoid aeration was necessary because of the volatility of ammonia and hydrogen sulfide, which were 2 of the toxic constituents known to be present.

Chemical analyses of some of the test solutions were made for the toxic constituents involved, and for other pertinent characteristics such as alkalinity, pH, and D.O.

Detailed discussion of the fish toxicity results are included in Appendix B. Laboratory data are presented in Tables B-3 through B-8.

Samples were collected on 4 days in October at P-8.6, below the Deere plant waste stream and above the Bestwall plant waste stream. Test concentrations of samples containing 12 to 15 ppm nitrogen as ammonia were toxic to less than 50 percent of test fish. Concentrations of samples containing 25 ppm or more of nitrogen were toxic to all fish exposed.

Samples were collected on 3 days from P-6.1, below the Bestwall waste stream and above the National Gypsum waste stream. A test concentration of sample containing 0.6 ppm sulfide was toxic to 10 percent of the exposed fish. Concentrations containing 1 ppm or more of sulfide were toxic to all fish exposed.

One sample was collected from P-4.9, below the National Gypsum waste stream and above the GRDA steam plant waste stream. A test concentration of sample containing 0.4 ppm sulfide was toxic to 20 percent of the test fish. Concentrations of samples containing 1 ppm or more of sulfide were toxic to all fish exposed.

Samples were collected on one day at P-3.0 and P-1.7, below all sources of waste. Insufficient sulfide determinations were made on these samples to permit correlation of toxicity with sulfide content.

Four percent of the sample from P-3.0 and 5 percent of that from P-1.7 were toxic to all test fish.

Samples were collected on 4 days during October from the bottom of the creek at its mouth. Insufficient sulfide determinations were made to permit correlation of toxicity with sulfide content. The toxicity of the water from this point varied rather widely, probably because of variable mixtures of creek and lake waters. Exact quantitative testing was rendered difficult by volatility of the sulfide with even slight aeration, and by changes in sulfide on standing even briefly. Concentrations of samples that killed all test fish ranged from 15 to 30 percent, though one 40 percent concentration killed only 90 percent.

In general, the results of the toxicity tests agreed with commonly accepted values of toxicity of ammonia and sulfides to fish. Ammonia concentrations of 12 to 15 ppm were toxic to less than 50 percent of the test fish, while concentrations of 25 ppm or more were toxic to 100 percent of the fish exposed. Sulfide concentrations of about 0.5 ppm were toxic to small percentages of the test fish, but 1 ppm or more killed 100 percent of the fish exposed.

Concentrations of Pryor Creek water that were toxic to the test fish generally varied in the range of 2 to 15 percent for the 6 stations sampled, though a few samples were not toxic in concentrations greater than 15 percent. Some of the apparently low toxicities undoubtedly were the result of difficulties in handling the samples without causing changes in the highly volatile and unstable ammonia and hydrogen sulfide.

Bottom Organisms

Two sets of bottom samples were collected from 6 stations on Pryor Creek for determination of bottom organisms.

The results of bottom sampling are discussed in Appendix B, and data on organisms appear in Tables B-9 and B-10.

At P-14.0, above all pollution, 112 bottom organisms representing at least 14 species were obtained.

At P-10.8, below the Pryor sewage treatment plant, 43 organisms representing at least 6 species were collected. While both total organisms and species were less here than those above all pollution it is noteworthy that some of the organisms at P-10.8 were species that are quite sensitive to pollution. This indicated that the water quality here was satisfactory.

At station P-8.6, below the Deere plant waste stream, and at stations P-5.6 and P-1.0, below the sources of paper mill wastes, no bottom organisms were found.

At the mouth of Pryor Creek 3 organisms were found on one occasion and none on the other. Those found were tolerant of pollution.

The large numbers of bottom organisms and the variety of species found at the 2 upstream stations on Pryor Creek indicate water of satisfactory quality. By contrast, the virtually complete absence of bottom organisms at the 4 downstream stations reflects the results of serious pollution by the industrial wastes discharged to the creek.

Plankton Populations

Seven stations on Pryor Creek were sampled for determination of plankton populations. Collections ranged from 1 to 3 times at each station, with 2 samples taken at the majority of stations.

The results are reported in Appendix B, with data on the plankton found appearing in Tables B-11 through B-13.

At the 2 stations above all pollution, P-14.0 and P-10.0, a variety of plankton was found.

A variable plankton population was found at P-8.6, below the Deere plant waste stream. Nine kinds were found on one occasion, but only 3 kinds on the other. As noted earlier in the report water at this station frequently appeared bright green because of the abundant algae nourished by the nitrogen content of the stream at this point.

In the stream section below the sources of paper mill wastes and downstream to P-2.0 the stream supported little plankton except oscillatoria, which grows well in polluted water. Other life consisted of many mosquito larvae and small flies.

From P-1.5 to the mouth of the creek a variety of algae was present. Apparently these were carried upstream from Ft. Gibson Reservoir by the intrusion of lake water on the surface of the creek.

Ft. Gibson Reservoir

The original survey plan called for sampling Ft. Gibson Reservoir for a period of about one month. Results on the first samples collected from the reservoir at the beginning of October indicated that there was little probability of obtaining data during the month that would reflect significant effects of pollution from Pryor Creek. Consequently it was decided to limit collection for routine chemical analyses to 4 sets of samples from all stations.

Both the data obtained from the 4 sets of samples and experience on the reservoir during the 10 day sampling period confirmed the validity of the decision that prolonged sampling at that time was not justified. With the exception of D.O., which will be discussed later, the quality of water in the reservoir was found to be quite good. No problems in operation attributable to adverse water quality were reported at either of the 2 municipal water plants during the month. No fish kills occurred during that time.

In fact, no problems of poor water quality in the reservoir were detected during the entire 2 months of field operations, from late in August until late in October, when the biological field work was concluded.

Wastes from Pryor Creek

The high degree of natural purification of wastes occurring in Pryor Creek during the survey held the wastes entering Ft. Gibson Reservoir to a minimum. This prevented the wastes from exerting serious effects on quality of the reservoir water, even though stream flows in the reservoir were very low at the time.

The following daily quantities of waste materials found near the bottom at the mouth of Pryor Creek, P-0.0, during September are assumed to represent the daily quantities of pollution entering Ft. Gibson Reservoir during the reservoir sampling period.

Table 9

Waste Materials at Mouth of Pryor Creek

Constituent	Pounds Per Day
5 day B.O.D.	686
30 day B.O.D.	2,830
Total Nitrogen	251
Ammonia Nitrogen	194
Organic Nitrogen	56
Hydrogen Sulfide	695

It should be emphasized that the lack of natural flow in Pryor Creek, which permitted the wastes to be retained in the creek for about 54 days, was an important factor in the high degree of natural purification that occurred. The greater the natural flow in Pryor Creek the less will be the retention time during which natural purification can take place and the greater will be the quantities of waste reaching the reservoir. When the flow in Pryor Creek is about 25 cfs or greater the wastes will reach the reservoir with little reduction from the quantities discharged at the industrial plants. At 150 cfs detention time in the creek is only 1 day.

Stream Flows

Stream flows at the Chouteau gaging station in Ft. Gibson Reservoir were extremely low during October and November 1956 (Appendix D, Table D-5). The flows averaged 87.7 cfs for October and 90.4 cfs for November. During the first 10 days of October when samples were collected from the reservoir the average flow was 90.4 cfs. Minimum daily flow during both October and November was 69 cfs.

Average monthly flows immediately preceding and following the field survey are given in the following table.

Table 10

Average Monthly Flows - Ft. Gibson Reservoir

Month	Average Flow - cfs
July	1,741
August	1,562
September	616
October	87.7
November	84.8
December	639

On the basis of these flows, most of the water in the reservoir about the first of October had entered during July, August and September. If the water moved down the lake by total displacement the water entering in July and August, when the average flow for the 2 months period was 1,650 cfs, occupied the lower end of the reservoir from about mile 23.0 to the dam. Water entering in September, when the average flow was 616 cfs, occupied much of the upper end of the reservoir, from approximately mile 36.0 or 37.0 to mile 23.0. An appreciation of these flow data assists in understanding the results of reservoir sampling.

High flows in Pryor Creek for 2 days near the end of June had flushed the creek out thoroughly at that time (Appendix D, Table D-3). For the first 14 days in July the natural flow in Pryor Creek averaged about 3.4 cfs. Starting on July 15 there was no natural flow in Pryor Creek, and this condition persisted through January 1957, except for January 22, when a light rain caused a flow of 0.2 cfs for that day.

The above flow pattern in Pryor Creek probably means that the water passing the mouth of Pryor Creek during July and much of August, and sampled in the lower end of the reservoir in early October, probably received even less pollution from Pryor Creek than that found to be entering the reservoir during the September sampling period. The water passing the mouth of the creek in September and occupying most of the upper end of the reservoir in early October generally should show somewhat greater effects of pollution from the creek than for the 2 previous months.

It is obvious, however, in a situation so complex as this one that it is impossible to resolve the many variable factors which influenced the results found in the reservoir in such a way as to permit more than a general interpretation of the reservoir data.

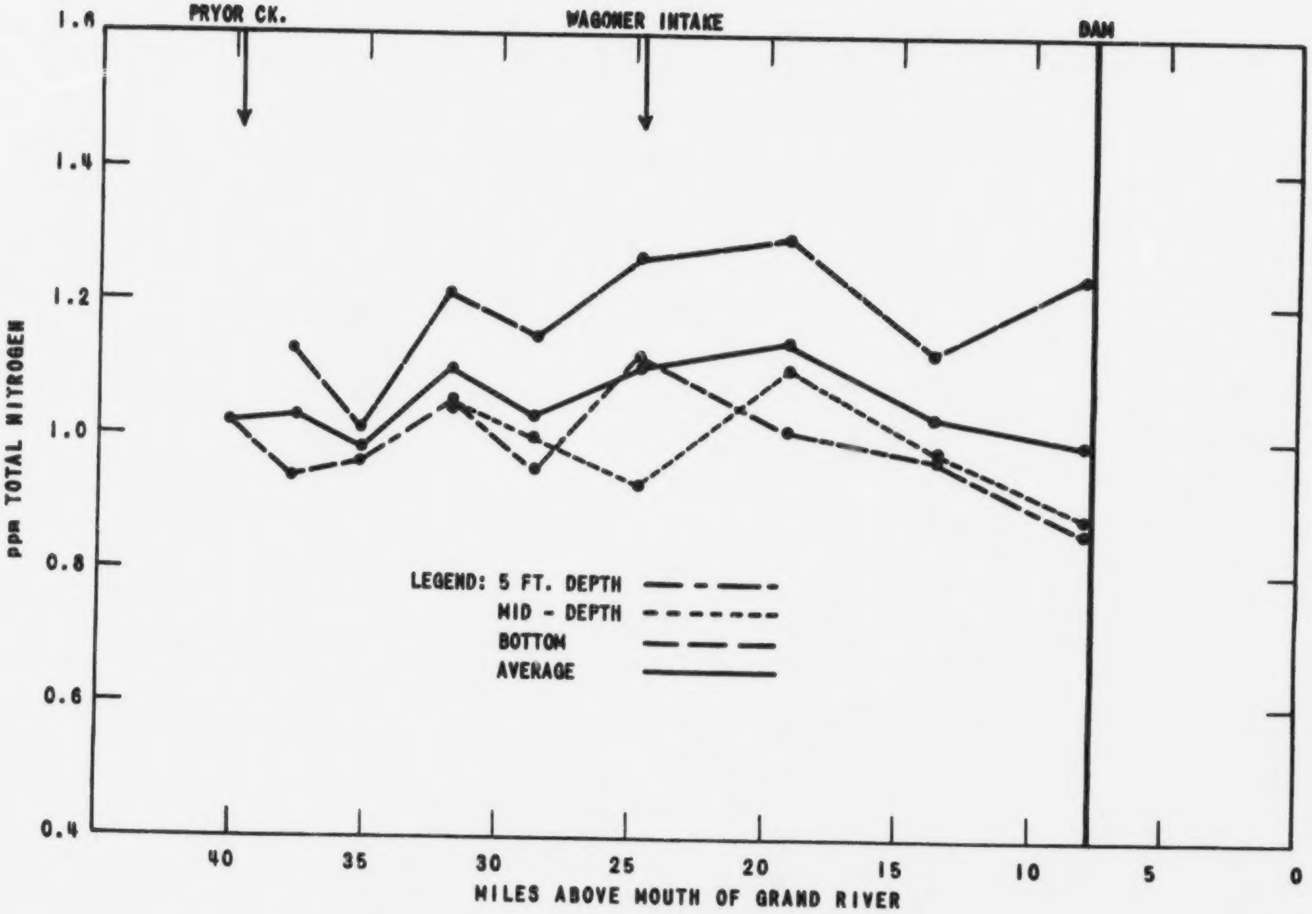
Nitrogen Compounds

The average results of total nitrogen determinations in Ft. Gibson Reservoir are shown in Figure 18.

Above the mouth of Pryor Creek, at G-40.0, the total nitrogen content of the water entering the reservoir was 1.02 ppm. This is in good agreement with the conclusion reached by others that the natural nitrogen content of Grand River in this area is about 1.0 ppm. This is assumed to be the natural nitrogen content throughout the reservoir.

In Table 9 it was shown that 251 pounds per day of total nitrogen was entering the reservoir during September. In the above discussion of flows in Ft. Gibson and Pryor Creek prior to reservoir sampling it was concluded that even less pollution than that found in September entered the reservoir in July and much of August.

Even if the full 251 pounds per day had entered the average flow of 1,650 cfs, which passed the mouth of Pryor Creek during July and August and was sampled in the lower end of the reservoir in October,



TOTAL NITROGEN IN FORT GIBSON LAKE

PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 18

the addition of total nitrogen to that naturally present in the reservoir water would have been less than 0.03 ppm. The results at 2 of the 3 stations in the lower end of the reservoir, G-7.7 and G-13.7, support this conclusion, yielding total nitrogen close to 1 ppm. The high nitrogen concentration of 1.14 ppm at G-19.2 can not be accounted for.

At the average September flow of 616 cfs, which occupied most of the upper end of the reservoir during early October, the 251 pounds per day of total nitrogen would have added 0.07 ppm of nitrogen to the reservoir water. The average nitrogen at 3 stations in this section, G-24.8, G-28.8, and G-31.9, was 1.08 ppm, or 0.05 ppm greater than the total nitrogen at G-40.0. The low value at G-35.2 can not be accounted for, but it is possible that the water sampled at this station passed the mouth of Pryor Creek when flow in the reservoir was much greater than the monthly average of 616 cfs.

Although quite small quantities and extremely small changes in concentrations were involved it is gratifying that results at 5 of 7 stations appear in general agreement with the known circumstances.

The nitrogen results at G-37.7, immediately below Pryor Creek, averaged only 0.013 ppm higher than at G-40.0, above Pryor Creek. Flows in the reservoir on the sampling dates averaged 129 cfs. The 251 pounds per day of total nitrogen from Pryor Creek would add 0.36 ppm of nitrogen to this quantity of flow, to give 1.38 ppm at G-37.7. Actually, however, the average flow past Pryor Creek that established the concentration at G-37.7 was much higher than the average for the sampling dates. On September 29 there was a high flow of 1,180 cfs, which filled much of the reservoir section between the mouth of Pryor Creek and G-37.7. This was followed by lower flows during the remaining days of the reservoir sampling period. As a result the relatively large volume of water that passed the mouth of Pryor Creek on September 29 took several days to pass G-37.7. Two of the 4 samples collected at G-37.7 represented water that had passed Pryor Creek on the one day, September 29. The third and fourth samples were collected from water that had passed the creek at 238 cfs, on September 30, and at 103 cfs on October 2. On this basis the expected increase in total nitrogen at G-37.7 is 0.07 ppm. This indicates that the average value found should have been 1.09 compared to the reported value of 1.03. There is 6 percent difference between the two values, which is within the limits of accuracy of the analytical procedures.

The discussion of total nitrogen values has been rather detailed, to show reasons for the general pattern of findings in the reservoir and to illustrate methods of interpretations that might be applied to all data. Little of value in the solution of the principal problem would result from detailed discussion and interpretation of all data, and subsequent discussion will be limited to the more pertinent findings.

Figures 19 and 20 present results of ammonia and of organic nitrogen determinations in the reservoir.

Total nitrogen, which consists of organic, ammonia, nitrite, and nitrate nitrogen, may be expected to persist through the reservoir at approximately the same levels at which it enters. However, the four nitrogen compounds constituting total nitrogen are constantly changing from one form to another under the biological influences exerted on them. Even the nitrites and nitrates, which vary only little throughout the reservoir, are merely transitional forms between ammonia and organic nitrogen, being constantly depleted and replenished.

The ammonia at G-40.0, above Pryor Creek, averaged 0.33 ppm. Although there were irregularities in trend, the ammonia generally tended to reduce as it passed through the reservoir. The average at the dam, G-7.7, was 0.16 ppm. This decrease does not necessarily indicate that it represented a reduction of 0.17 ppm at a constant rate through the reservoir. It is quite probable that the ammonia passed through several oxidation and reduction cycles while in the reservoir, and that the sum total of the changes in ammonia was much greater than the indicated reduction.

The organic nitrogen showed a general tendency to increase in passing through the reservoir. This was corollary to the decrease in ammonia, which presumably was oxidized to nitrite and nitrate nitrogen and then was metabolized into living plankton in the form of organic nitrogen. Here again the change probably represents several cycles in the reservoir, with the plankton dying, decomposing to yield ammonia, and starting the cycle again.

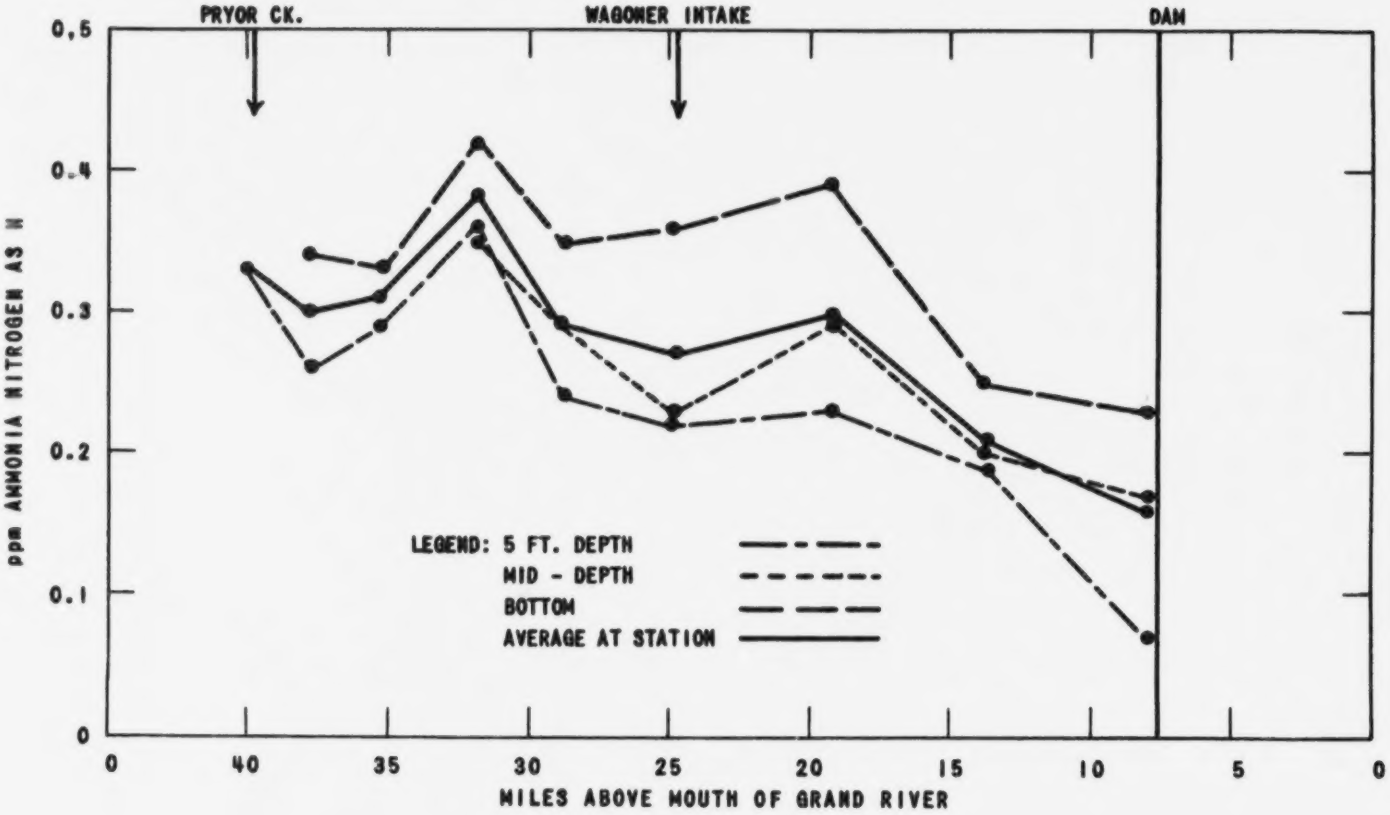
The significance of these nitrogen cycles will become apparent in the subsequent discussions of B.O.D. and D.O.

Oxygen Demand

The 5 and 30 day B.O.D. averages in Ft. Gibson Reservoir are shown in Figures 21 and 22.

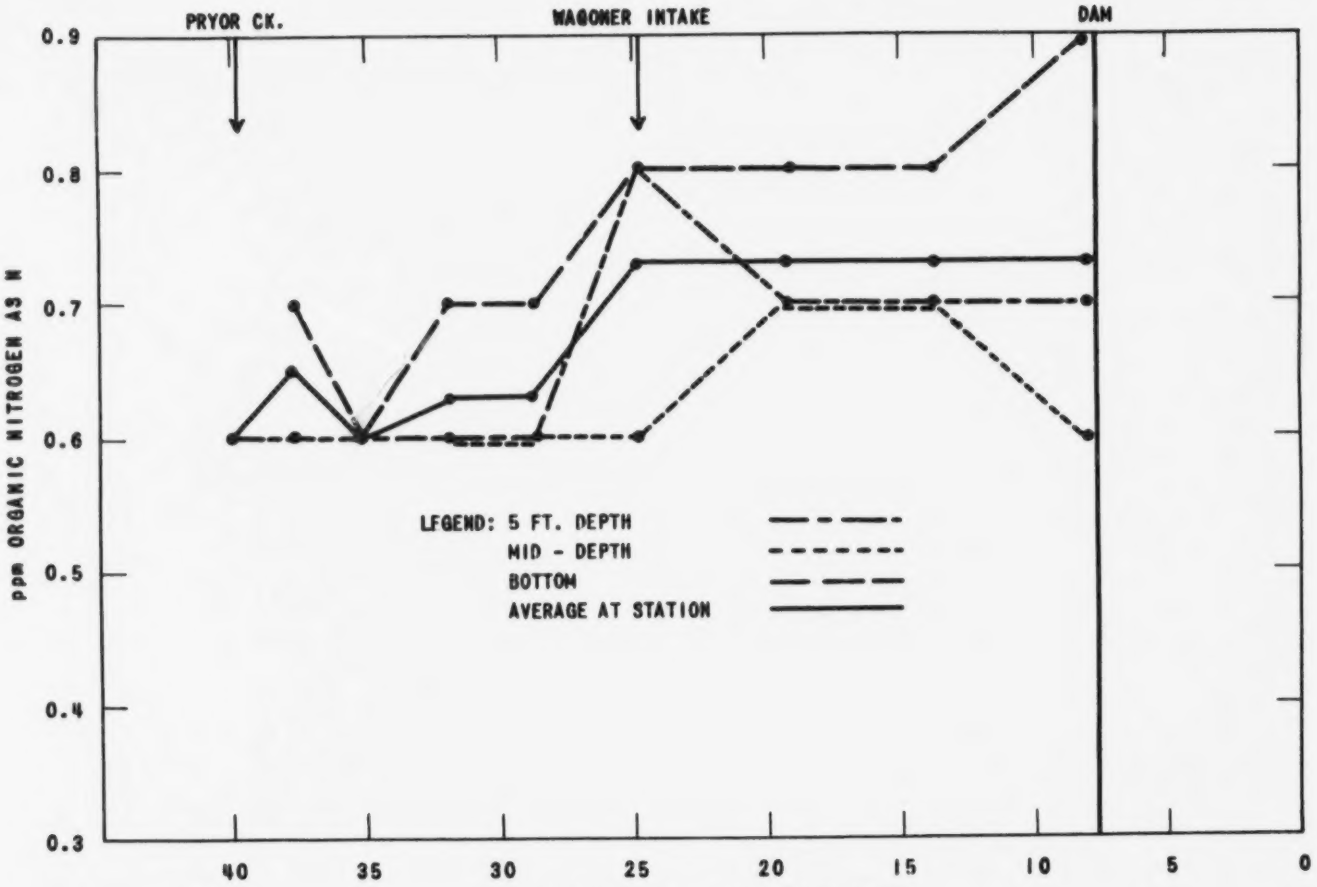
In general the 5 day values exhibit trends similar to those for total nitrogen. Averages in the lower section of the reservoir were very nearly the same as the 1.5 ppm at G-40.0, above Pryor Creek, and those in the upper section were generally slightly higher than that of the water entering the reservoir. As in the case of the total nitrogen, negligible 5 day B.O.D. (about 0.13 ppm) was added by Pryor Creek to the flow in the reservoir that was sampled at G-37.7.

In any event, the 5 day B.O.D. throughout the reservoir did not vary from 1.5 ppm by more than 13 percent. Since the limit of accuracy of the B.O.D. method is about 10 percent, the variations found were not highly significant. It appears that Ft. Gibson water has a minimum of about 1.5 ppm below which the 5 day B.O.D. does not drop. This probably is associated with the continuing development, death and decay



AMMONIA NITROGEN IN FORT GIBSON LAKE

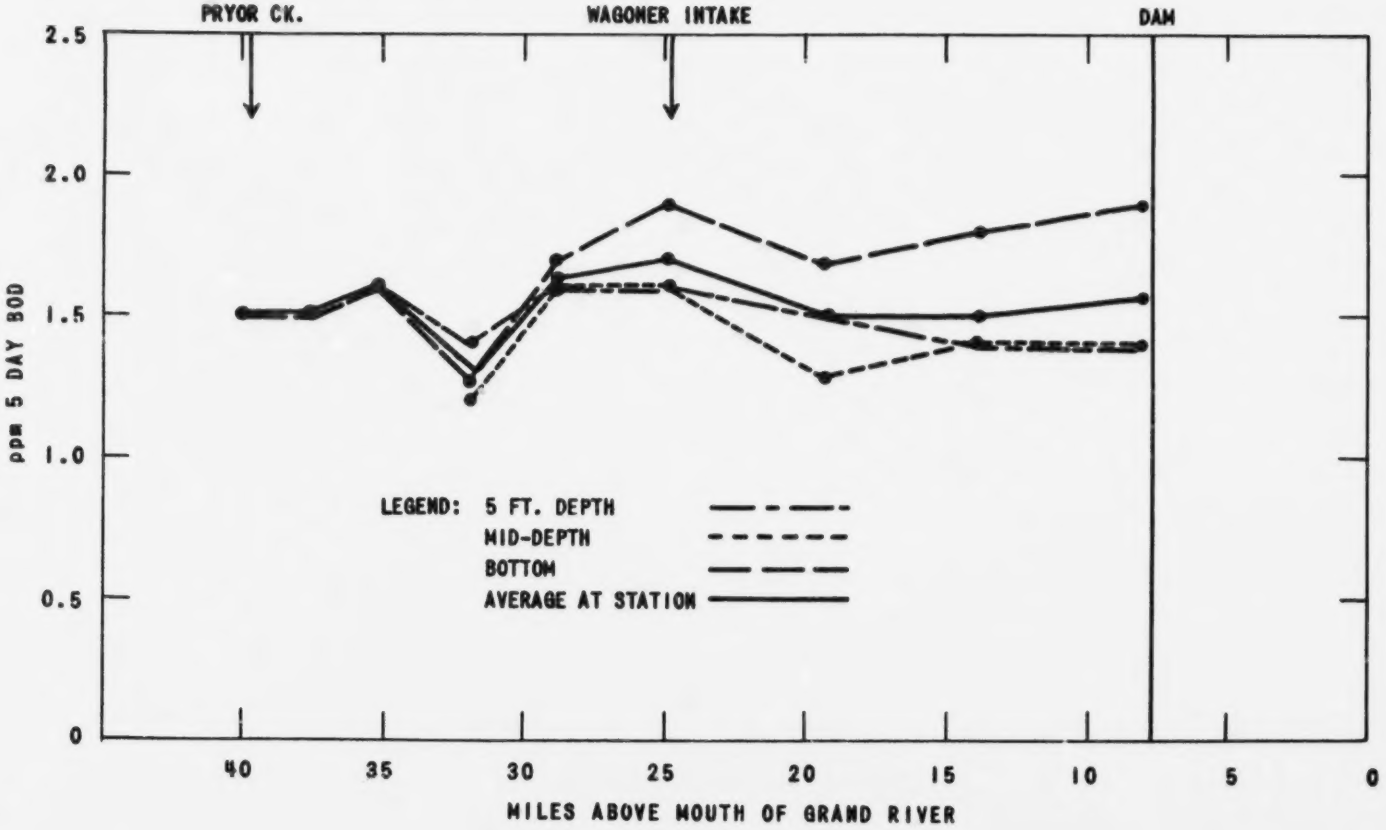
PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 19



MILES ABOVE MOUTH OF GRAND RIVER

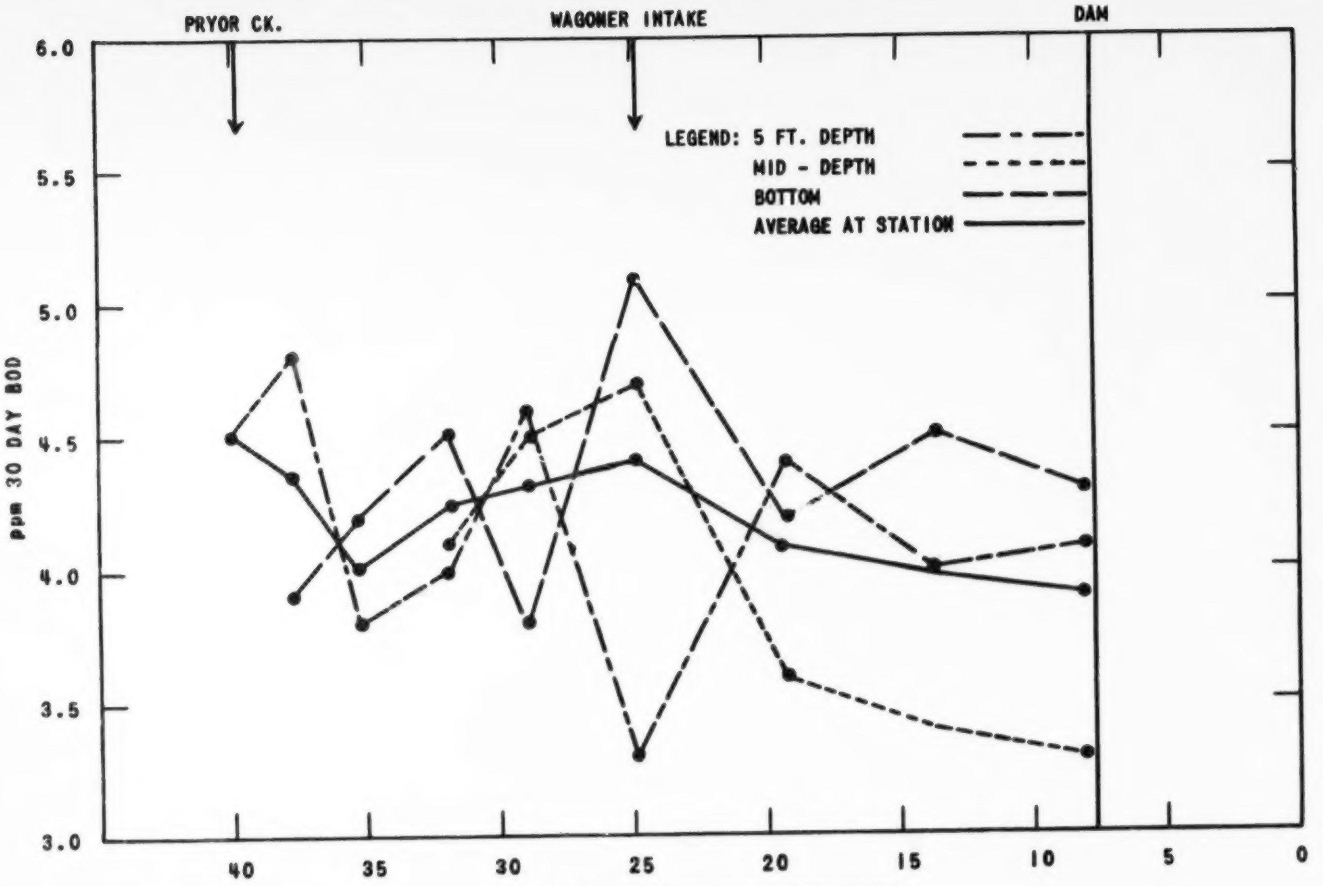
ORGANIC NITROGEN IN FORT GIBSON LAKE

PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 20



5 DAY BOD IN FORT GIBSON LAKE

PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 21



30 DAY BOD IN FORT GIBSON LAKE

PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 22

of plankton discussed in connection with nitrogen compounds. This would mean that a continuing daily B.O.D. of about 0.4 to 0.5 ppm is exerted throughout the reservoir.

The 30 day B.O.D. exhibits an erratic but generally decreasing trend as the water passes down the reservoir. The over-all decrease is only 0.6 ppm, or about 13 percent of the 4.5 ppm at G-40.0. This is a very small reduction for the 3 months that the water at G-7.7 had been in the lake. Here again recycling of oxygen demanding materials through the bodies of plankton may have been a significant factor in the persistence of the B.O.D.

In any event, it is obvious that the B.O.D. in Ft. Gibson Reservoir did not follow the usual course of decrease at a constant rate which is considered typical of a polluted stream. A constant rate of decrease in B.O.D. is one of the mathematical bases for the oxygen sag curve analysis that is used in estimating the oxygen demand load that a stream can assimilate.

Dissolved Oxygen

The D.O. averages found in Ft. Gibson Reservoir are shown in Figure 23.

The averages indicate a drop of 1.2 ppm from G-40.0 to G-31.9, below Pryor Creek. Although this drop resembles that which commonly occurs below a source of waste it does not appear that it can be accounted for by the approximately 0.2 ppm each of 5 day B.O.D. and of hydrogen sulfide added to the flow in the reservoir by wastes from Pryor Creek.

It appears probable that the D.O. variations found in the reservoir reflected the D.O. content of the water entering Ft. Gibson Reservoir from upstream rather than the effects of pollution from Pryor Creek during the summer of 1956. The D.O. content of Grand River water entering the reservoir is directly related to the stream flow in the river between Pensacola Dam and the upper end of Ft. Gibson Reservoir and to the thermal stratification that occurs in Grand Lake O' the Cherokees. The thermal stratification causes oxygen depletion in the bottom stratum of the reservoir from which water is withdrawn through the turbines.

Time was not available for a thorough investigation of this phase of the problem during the survey. Experience elsewhere with similar situations confirms the limited data obtained in the local situation.

Large, deep reservoirs stratify thermally into 3 distinct strata during summer. The cold, dense, bottom stratum is excluded from the atmosphere by the 2 overlying strata. In the absence of reaeration the

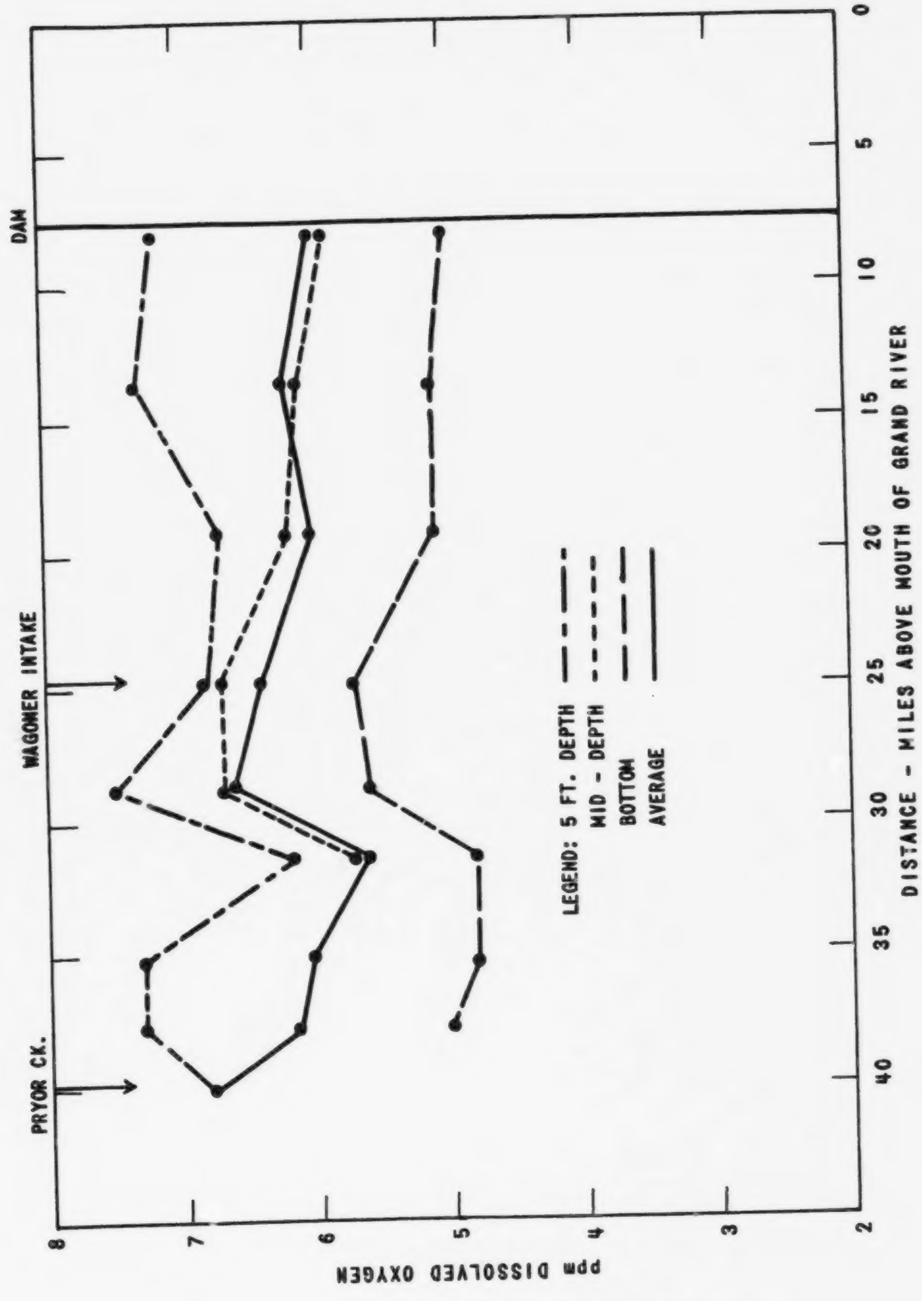
D.O. of the bottom stratum is totally or very nearly totally depleted by the natural oxygen demand of the water during the 5 to 6 months that stratification persists. Modern hydroelectric turbines withdraw water through penstocks with intakes deep in the reservoir, usually in the bottom stratum. The water withdrawn from the bottom stratum may be 10 to 20°F colder than surface water temperatures and contains little or no D.O. The water generally picks up less than 1 ppm in the turbulent tailrace.

The stream below the dam recovers the depleted D.O. by reaeration of the flowing water. Many miles may be required, however, to restore the D.O. of the stream to or near saturation. In several cases D.O. as low as 3 to 5 ppm has been found as far as 30 to 50 miles below such dams. The recovery of D.O. concentration below the dam varies inversely with the stream flow. At low stream flows a stream may recover to 5 or 6 ppm of D.O. in 30 miles, for example, but at high flows may recover to only 2 or 3 ppm.

The evidence of typical stratification and D.O. depletion in the bottom stratum was confirmed in Grand Lake O' the Cherokees by sampling just above the dam early in the survey. Failure of Grand River to recover D.O. to or near saturation at the upper end of Ft. Gibson Reservoir is confirmed by the results of sampling at G-40.0, above the mouth of Pryor Creek. Values obtained on 4 samples were 5.0, 5.7, 8.2 and 8.4 ppm of D.O., with an average of 6.8 ppm. Corresponding D.O. saturation values were 55.3, 64.2, 93.2 and 95.6 percent, with an average of 74.1 percent. These samples were collected during a period when stream flows ranged from 78 to 120 cfs. When stream flows are several hundred to a few thousand cfs, water with even lower D.O. probably reaches Ft. Gibson Reservoir.

This phenomenon probably was a major factor in the low and variable D.O. values found in Ft. Gibson Reservoir. Most of the averages were in the vicinity of 6 ppm, despite opportunity for reaeration in the reservoir. The minimum average found was 5.6 ppm, corresponding to a D.O. saturation of 63.0 percent at G-31.9. Average saturation at 6 of the 9 reservoir stations was less than 70 percent. The highest average D.O. found below Pryor Creek was 6.60 ppm, corresponding to a saturation of only 73.8 percent, at G-28.8. It is obvious that reaeration in the reservoir is not very effective in restoring D.O. With effective reaeration and the long detention time involved D.O. would be expected to approach saturation in at least the lower half of the reservoir.

Several factors contribute to the relatively low level of D.O. in the reservoir. Compared to most uncontrolled streams depths and velocities of flow in most of the Ft. Gibson Reservoir are quite low. Both of these factors are unfavorable to effective reaeration.



DISSOLVED OXYGEN IN FORT GIBSON LAKE

PRYOR CREEK - FORT GIBSON LAKE SURVEY

FIGURE 23

A further deterrent to reaeration is the thermal stratification that occurs in Ft. Gibson Reservoir. The stratification pattern is not of the classical 3 strata type described for Grand Lake O' the Cherokees, but is one of a gradual temperature drop from top to bottom of the reservoir. This is illustrated in Figure 24 by the results of temperature measurements made near the end of September. Temperature differences in the upstream half of the reservoir were about 1.5°F from top to bottom, but in the downstream half they were as much as 4 to 5°F. Earlier in the year, on July 20 when atmospheric temperatures were higher than they were in late September, a difference of 7°F between the surface and the bottom was found just above the dam by the U. S. Corps of Engineers. At that time 5°F of the temperature drop occurred in the top 10 feet of water. This type of stratification resists mixing of water from top to bottom of the reservoir and reduces the effectiveness of reaeration.

The estimated 0.4 to 0.5 ppm per day of oxygen demand throughout the reservoir exerts a continuing depletion on the D.O. of the reservoir.

The combined effect of the above factors is to hold D.O throughout the reservoir to levels considerably below saturation values.

It is obvious that the many complicating factors in Ft. Gibson Reservoir, which do not occur in uncontrolled streams, prevent reliable application of the usual principals of stream analysis by the oxygen sag curve technique to the determination of a permissible oxygen demand load on the reservoir water.

Further complications to an already complex D.O. situation can result if the proposed Markham Ferry Dam and Reservoir materialize. This reservoir would flood most of the remaining section of open river between Pensacola Dam and the upper end of Ft. Gibson Reservoir. If the penstock intakes are installed deep in the new reservoir, as is common practice, the cold, low D.O. water from Grand Lake O' the Cherokees will flow as a density underflow along the bottom of Markham Ferry Reservoir and through the penstocks into the upper end of Ft. Gibson Reservoir. A warm stratum of water, similar to that above Ft. Gibson Dam (Figure 24), will develop and float on top of the density underflow and will essentially exclude natural reaeration. Water with little if any more D.O. than that discharged below Pensacola Dam will arrive at the upper end of Ft. Gibson Reservoir. Much lower D.O. levels than those found during the survey could occur in Ft. Gibson Reservoir under these circumstances.

The only known solution of this problem is the installation of penstock intakes close enough to the surface of the reservoir to minimize the warm surface layer of water and thus to permit the cold water to maintain contact with the atmosphere and regain D.O. by reaeration.

Alkalinity and pH

Both alkalinity and pH throughout Ft. Gibson Reservoir were quite normal for a natural stream.

Average alkalinity varied only slightly from 100 ppm. Average pH values varied in the relatively narrow range of 7.4 to 7.8.

There was no evidence during the survey of the high alkalinity or pH which had been reported as an occasional cause of water treatment problems at Wagoner.

Coliform Organisms

The coliform organism results indicated the water in the reservoir was remarkably free from any serious effects of sewage pollution.

The highest most probable number (MPN) of coliform organisms found was 560 per 100 ml (logarithmic average) at G-24.8, opposite the Wagoner water works intake. This probably was caused by sewage discharged from a few lake front houses a short distance above the sampling station. The MPN was only about one-ninth of the monthly average coliform concentration permissible in the raw water of a plant equipped with the treatment facilities provided at Wagoner.

The next highest MPN was 220 per 100 ml at G-40.0, above the mouth of Pryor Creek. This may have reflected the residual bacterial contamination from the few small sewered communities on tributaries of Grand River below Pensacola Dam.

At G-35.2, below Pryor Creek, the MPN was 110 per 100 ml.

At the other 6 stations on the reservoir the MPN ranged between 20 and 50 per 100 ml.

The over-all bacterial quality of water in the reservoir was excellent for water supply use, following conventional treatment. It was suitable, especially in the lower half, for all of the recreational uses that are popular on this body of water.

Color

The color of the water in Ft. Gibson was quite low with average values generally in the range of 5 to 10 ppm.

The color was slightly higher in the 9 miles below Pryor Creek than it was above Pryor Creek and in the lower half of the reservoir.

From just below Pryor Creek, G-37.7 to G-28.8 the averages tended to group around 10 ppm. At all other stations the averages generally were 5 ppm or a little higher.

Bottom Organisms

Samples for determination of bottom organisms were taken from 2 stations above Pryor Creek and 2 stations below Pryor Creek. One station was at the "low water bridge," mile 43.5, which is at the extreme upper end of Ft. Gibson Reservoir. Another station was at G-40, a short distance above Pryor Creek. The 2 stations below the mouth of the creek were at Highway 33 Bridge, mile 39.0, and at the Wagoner water works intake, mile 24.8.

The 2 sets of samples, collected in late August and early October, were obtained with some difficulty because of the nature of the reservoir bottom. The organisms obtained and general observations indicated that a normal bottom fauna existed in the reservoir both above and below Pryor Creek.

This information supports the conclusion reached earlier on the basis of hydrology and chemical results that pollution of Ft. Gibson Reservoir by Pryor Creek had not been serious at least since the end of June 1956.

Plankton Populations

Three sets of plankton samples were collected from the reservoir in early and middle September and in early October. Stations used were the same as those for bottom organisms.

A fairly large variety of plankton populations was found. The variety of kinds was such as is normally expected in ordinary surface water. Sampling was not sufficient to provide a basis for evaluation of possible increases in plankton below Pryor Creek that might affect water used for domestic purposes.

POTENTIAL POLLUTION OF RESERVOIR

No interference with water uses by pollution in the reservoir was found during the field operations. The data obtained, however, provide a basis for conclusions regarding conditions that have caused problems in water treatment and fish kills.

Charts have been prepared showing concentrations of selected pollutants that may occur in the reservoir following rapid flushing of

Pryor Creek (Figures 24 through 27). These curves are based on accumulations of the same quantities of pollutants in Pryor Creek as were found during the September 1956 survey. They show the predicted concentrations of pollutants in a number of selected flows in Ft. Gibson Reservoir for various flows in Pryor Creek. Within limits, increasing concentrations of pollutants in the reservoir will result from increasing flows in Pryor Creek because the higher flows flush the accumulated pollution more rapidly into the reservoir.

Water Supply

The principal problems that may be attributed to pollution at the Wagoner water supply have been interference with chlorination to a free chlorine residual, taste and odor, and high pH.

pH

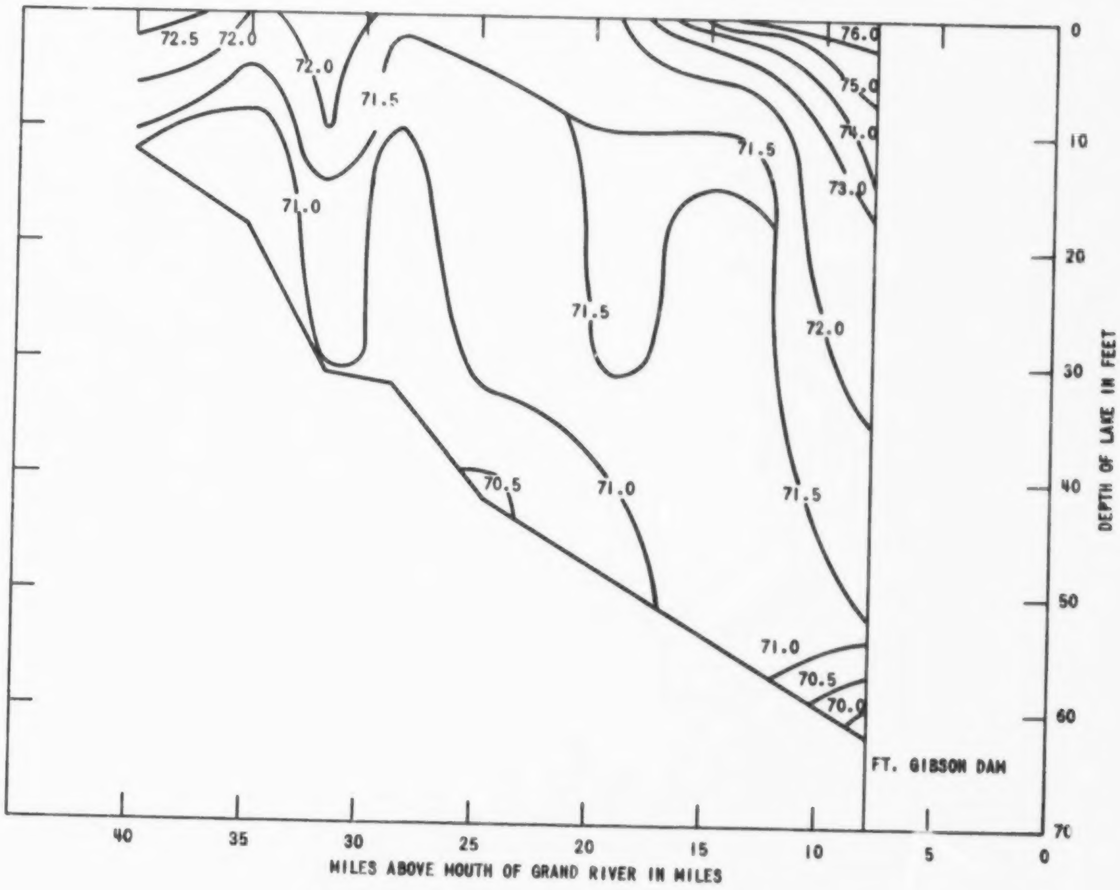
Of the 3 problems, no cause for the occasional high and erratic pH previously reported at the Wagoner water plant was found in Pryor Creek during the field survey.

The highest pH values found were below the points of discharge of the Pryor sewage treatment plant and the Deere plant. Below the sewage treatment plant alkalinity was only slightly above normal levels for the area, averaging 134 ppm. Below the Deere plant the alkalinity averaged nearly 1,500 ppm. Both pH and alkalinity were reduced downstream by dilution with wastes, from the 2 paper mills, which had moderately low pH and alkalinity.

The data do not indicate that even a rapid flushing of Pryor Creek at that time would have caused high pH or alkalinity in the reservoir.

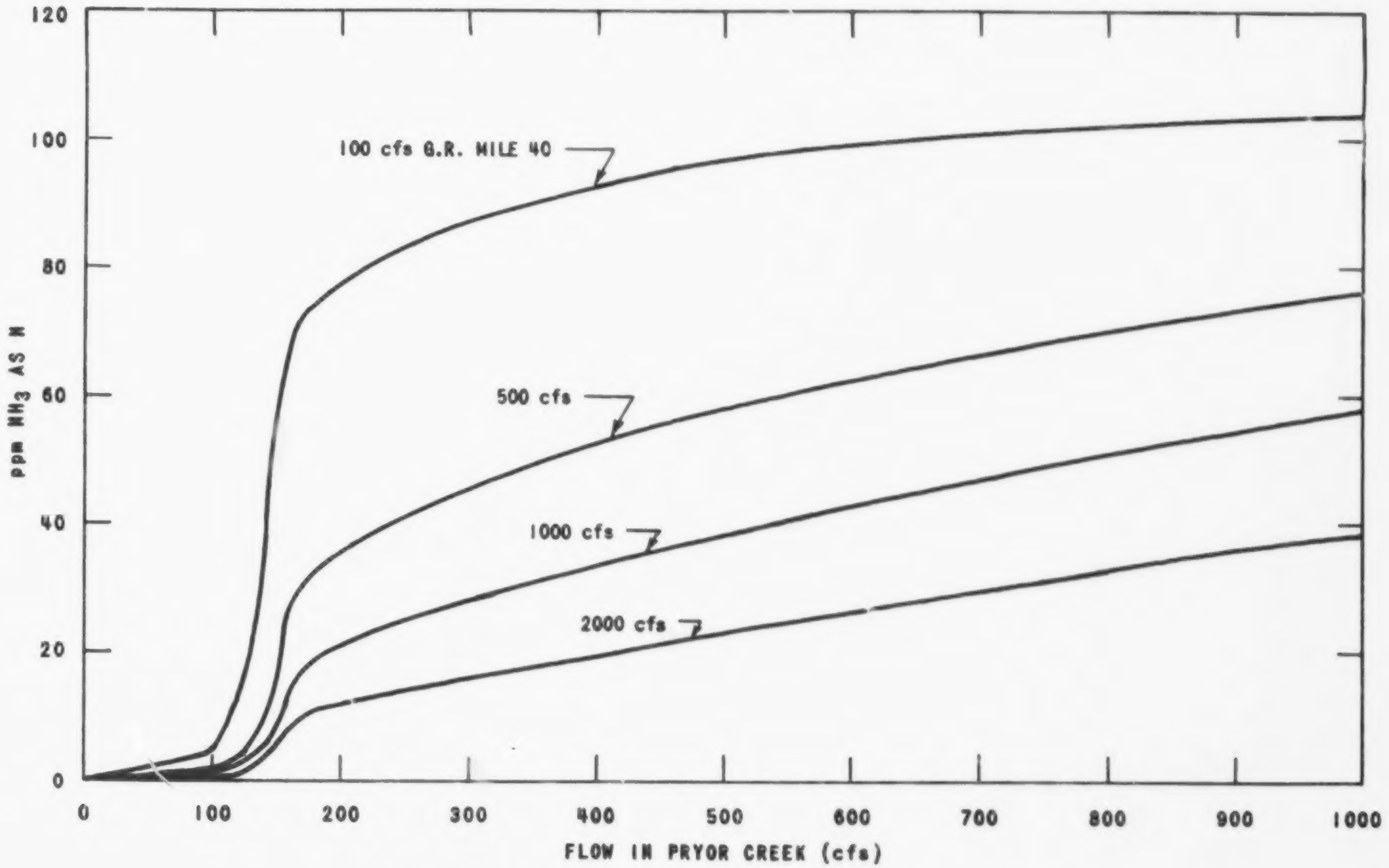
The Deere plant is known to use quantities of caustic soda in one step of the manufacturing process. After use this highly alkaline material is discharged to the waste lagoon, where sulfuric acid is added for neutralization. Special facilities for control of neutralization were not provided originally and it is probable that neutralization was not always effective. It is possible, though not positively established, that this situation may have contributed to the pH problem at the Wagoner water plant.

It is reported that special facilities for control of caustic neutralization have been provided at the Deere plant. If this waste was the former cause of high pH, proper operation of the neutralization process should assure that this problem will not recur.



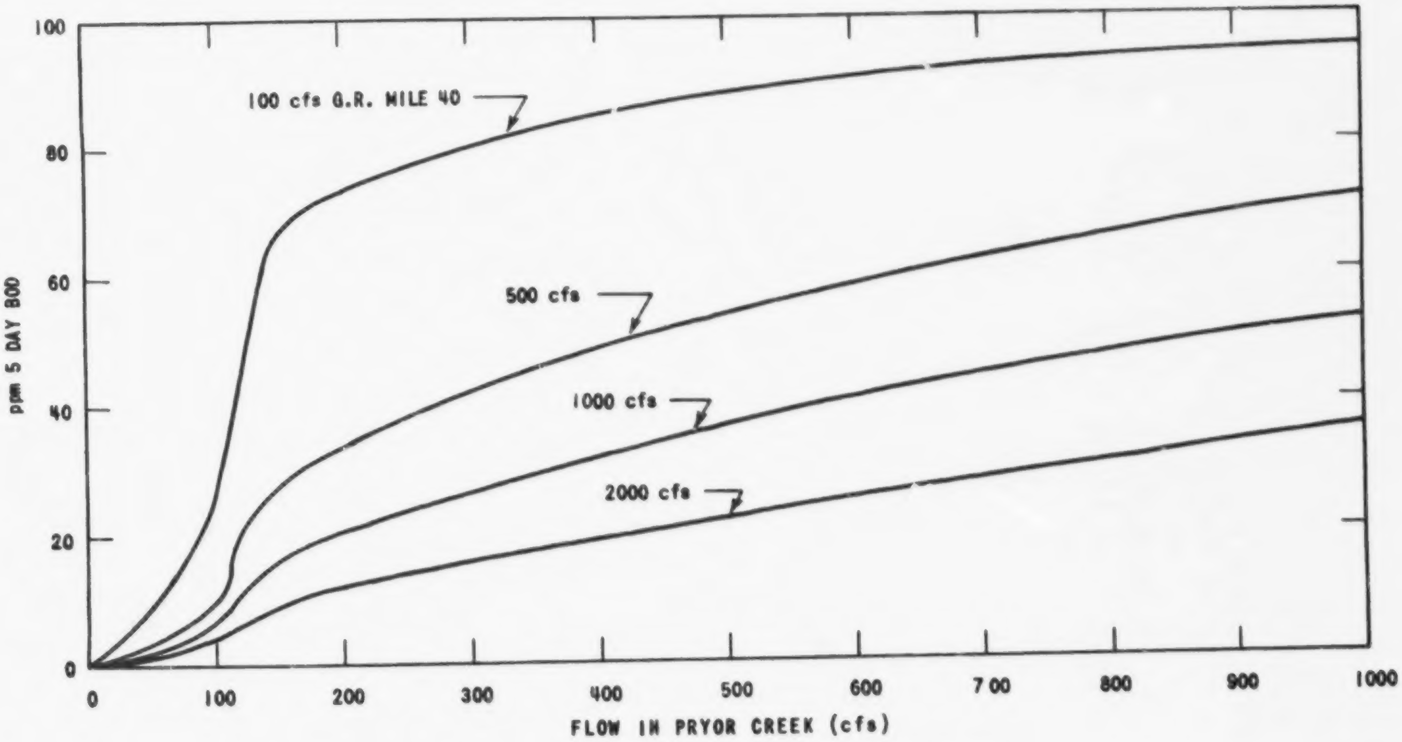
TEMPERATURE PROFILE OF FT. GIBSON LAKE
SEPT. 26 AND 28, 1956 - TEMP. °F

PRYOR CREEK - FT. GIBSON LAKE SURVEY
FIGURE 24



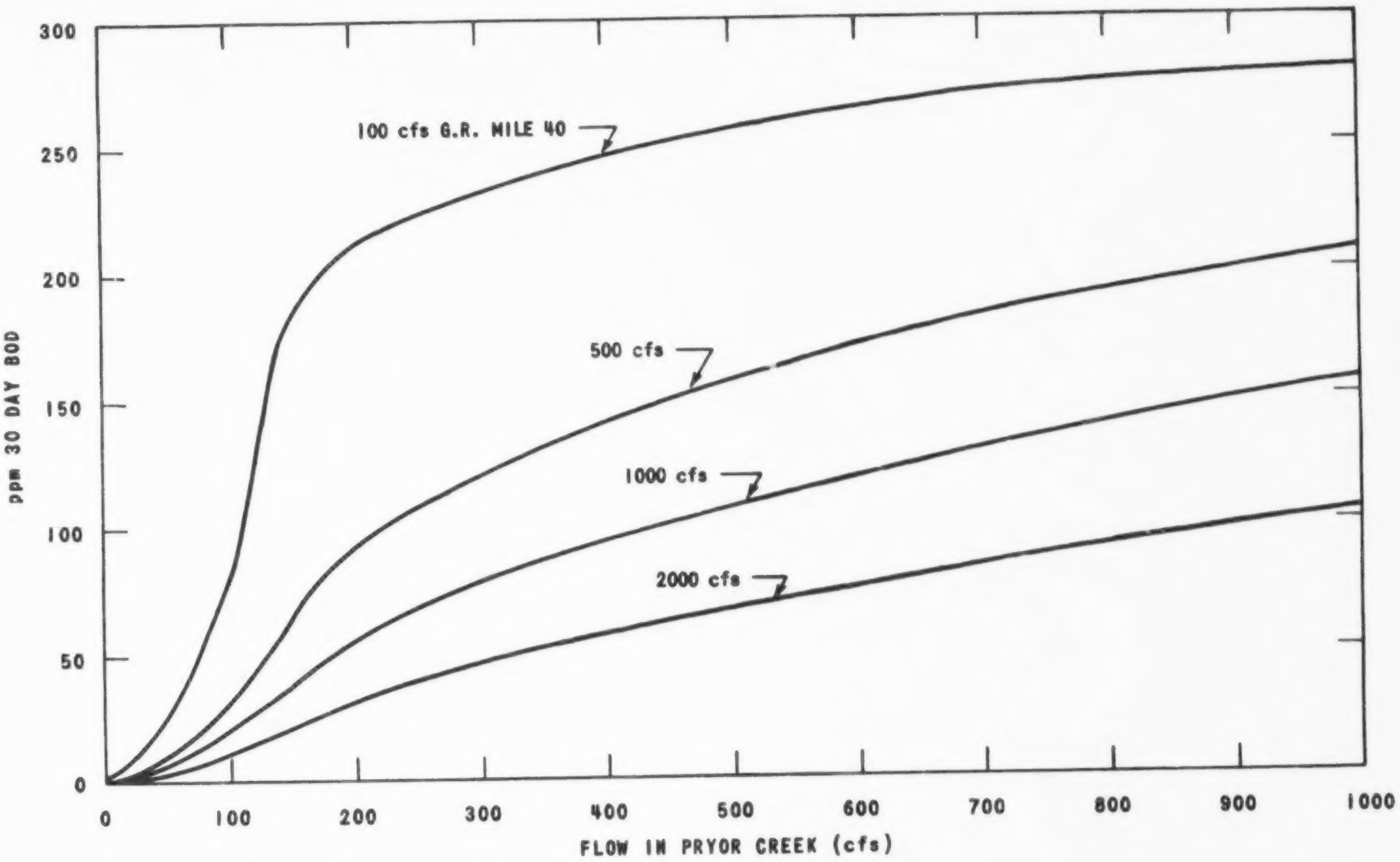
NH_3 CONC. IN FORT GIBSON LAKE AT VARIOUS FLOWS IN GRAND RIVER AND PRYOR CREEK

PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 25



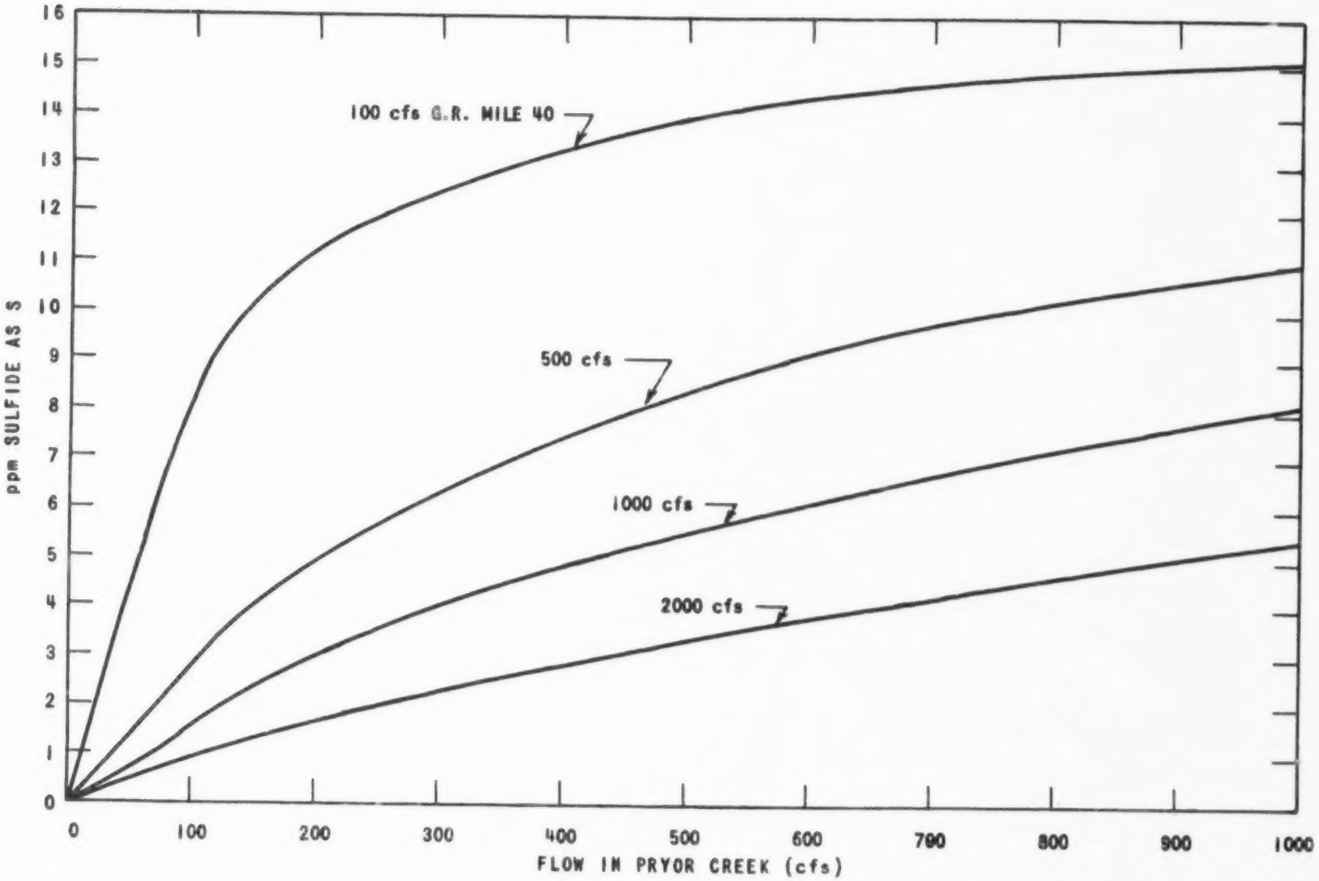
5 DAY BOD IN FORT GIBSON LAKE AT VARIOUS FLOWS
IN GRAND RIVER AND PRYOR CREEK

PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 26



30 DAY BOD IN FORT GIBSON LAKE AT VARIOUS FLOWS
IN GRAND RIVER AND PRYOR CREEK

PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 27



SULFIDE CONC. IN FORT GIBSON LAKE AT VARIOUS FLOWS IN GRAND RIVER AND PRYOR CREEK

PRYOR CREEK - FORT GIBSON LAKE SURVEY
FIGURE 28

Chlorination

Chlorination of water for disinfection may be carried only to the production of chloramines (combinations of chlorine and ammonia) or it may be carried to complete oxidation of ammonia and the production of a free chlorine residual in the water.

Chlorination to a free residual has advantages over "partial" chlorination which have led to its use in most municipal water treatment plants. A free chlorine residual kills bacteria much more quickly than do chloramines. In addition, free chlorine controls most tastes and odors in water more effectively than the chloramines do.

During the field survey the Wagoner water treatment plant was chlorinating to a free residual. The chlorinator capacity provided a chlorine dosage of 8 to 10 ppm. Operating practice at this plant is designed to maintain 2 ppm of free chlorine residual in the treated water. This means that the chlorination capacity at the plant provided 6 to 8 ppm of chlorine for oxidation of ammonia and other constituents of the water that would react with chlorine.

The amount of chlorine required for complete oxidation of ammonia varies rather widely depending on characteristics of the water. In general around 10 ppm of chlorine is required for 1 ppm of ammonia nitrogen.

The ammonia in Ft. Gibson Reservoir above Pryor Creek during the field survey averaged 0.33 ppm. At the Wagoner water intake it averaged 0.27 ppm and the average for the entire reservoir was 0.28 ppm. It has been noted in the discussion of results in Ft. Gibson Reservoir that water in the reservoir during the sampling period had received very low concentrations of pollutional constituents from Pryor Creek. Addition of waste ammonia to the water in the lower half of the lake is computed to have been a little over 0.02 ppm, and to water in most of the upper half of the reservoir a little less than 0.06 ppm.

The natural ammonia content of the reservoir, about 0.3 ppm, would require about 3 ppm of chlorine for oxidation if the 10 to 1 ratio applies to this water. This means that a chlorine dosage of 5 to 6 or 7 ppm should have been adequate to produce a free residual of about 2 ppm. The actual dosage used at the plant during the survey period was about 7 to 8 ppm.

Even a small addition of ammonia to the reservoir water by the wastes from Pryor Creek at that time could have increased the ammonia content of the raw water at the Wagoner plant sufficiently to exceed the chlorination capacity for producing a free chlorine residual. An addition of 0.4 ppm of ammonia nitrogen, to give a total of 0.7 ppm, probably would have prevented chlorination to a free residual.

Following the survey the Wagoner water plant chlorination capacity was increased to 20 ppm, which should assure the desired 2 ppm of free residual if ammonia in the raw water did not exceed about 1.4 to 1.6 ppm. The Wagoner Superintendent of utilities has reported that even the increased chlorination capacity was not adequate to produce a free residual at times during the past winter.

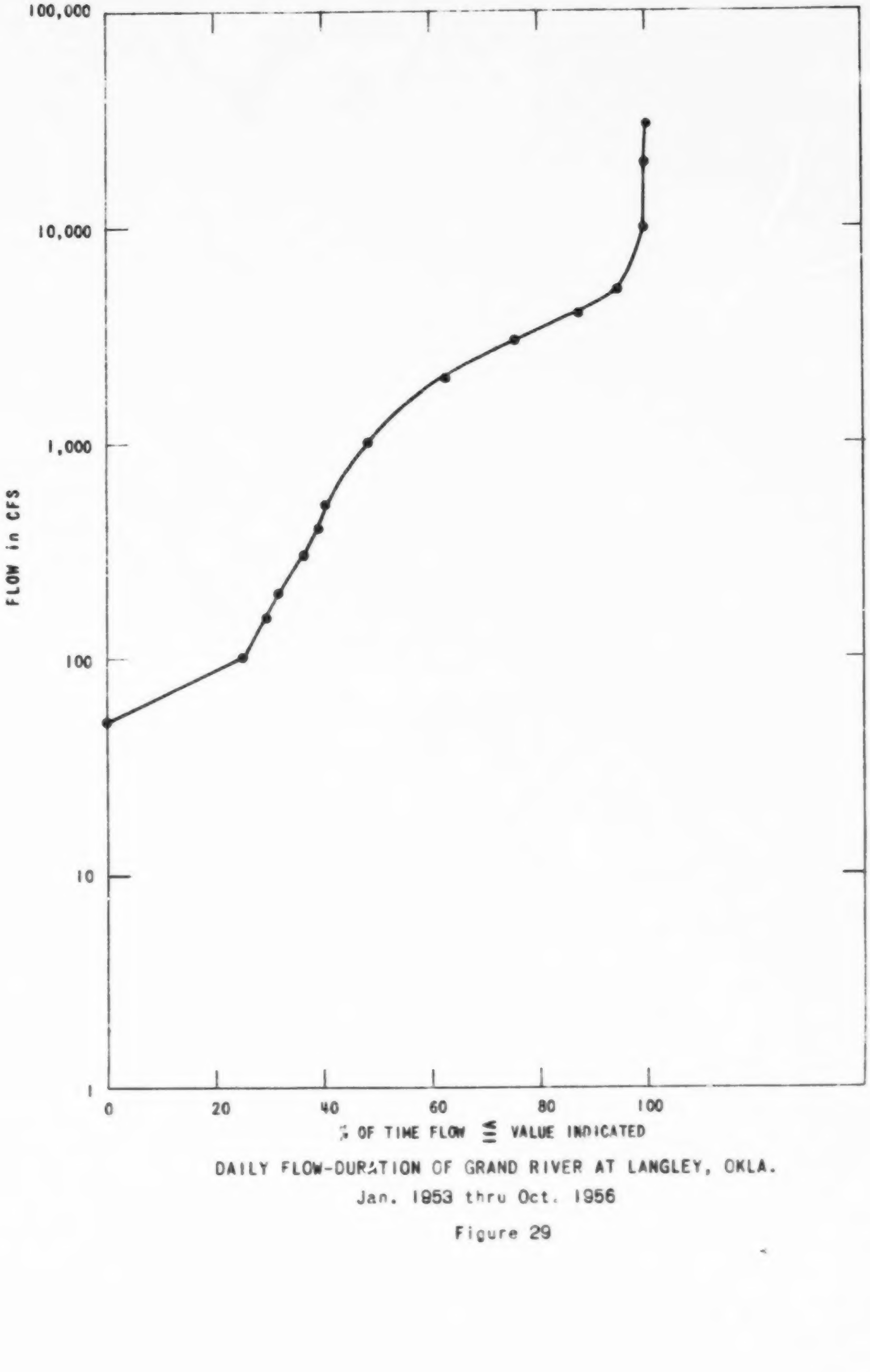
Difficulties in chlorination at Wagoner have been reported to occur most frequently in winter. This is logical, since ammonia persists, without oxidation, much longer in cold than in warm water. Whereas biological oxidation of ammonia may be expected to start in about 5 to 10 days in water at summer temperature there may be no change in ammonia in 3 to 4 weeks at winter temperature.

Two different sets of conditions in Pryor Creek could cause excessive ammonia to reach the Wagoner water intake. One set of conditions would be a sudden flushing of the creek following a period of low flow that permitted accumulation of wastes. The other condition would be a period of sustained moderate to high flows in Pryor Creek that would reduce the retention of wastes in the creek, with accompanying reduction in natural purification, and would permit all or most of the daily waste discharges to reach the reservoir.

Figure 25 illustrates the possible effects of the first set of condiitions on ammonia in the reservoir. With an accumulation of ammonia in Pryor Creek the same as that found in September 1956 (50 tons) a sudden increase in flow to 100 cfs could add concentrations of 2 ppm of ammonia to 500 cfs of flow in Ft. Gibson Reservoir, and of 5 ppm to 100 cfs of flow. Either of these concentrations at the Wagoner intake should exceed the capacity of chlorination equipment to produce a free chlorine residual. Average daily flows of 100 cfs in Pryor Creek occurred about 4 percent of the time during 1953-1956 (Figure 6). During approximately the same period daily flows in Ft. Gibson Reservoir were 100 cfs or less about 25 percent of the time (Figure 29). Daily flows of 500 cfs or less occurred about 40 percent of the time.

With the same conditions of accumulation in Pryor Creek but with a flushing flow of 200 cfs the concentration of ammonia in the reservoir would range from 12 ppm at 2,000 cfs to 77 ppm at 100 cfs. Flows of 200 cfs in Pryor Creek occurred about 2.5 percent of the time, and 2,000 cfs or less in Ft. Gibson 63 percent of the time.

A sustained flow of about 14 cfs in Pryor Creek would dilute the ammonia nitrogen from the Deere plant to about 50 ppm in the creek. It is not believed that there would be rapid loss of ammonia to the atmosphere at this concentration. If, in addition, essentially all the urea should be converted to ammonia in the creek a flow of about 27 cfs would be required to dilute the total ammonia to 50 ppm.



DAILY FLOW-DURATION OF GRAND RIVER AT LANGLEY, OKLA.
Jan. 1953 thru Oct. 1956

Figure 29

Twenty-seven cfs or more of daily flow occurred in Pryor Creek nearly 10 percent of the time (Figure 6). At a flow of 27 cfs the waste from the Deere plant would reach the reservoir in about 6 days. It is not believed that there would be significant loss of ammonia from the stream under these circumstances, especially during the winter.

If the total 7,300 pounds per day of nitrogen in the Deere wastes should arrive at the reservoir as ammonia it would add 2 ppm of ammonia to 675 cfs of flow in the reservoir. Daily flows of 675 cfs or less occurred in the Grand River at Langley 43 percent of the time (Figure 29). At flows less than this the ammonia concentrations would be correspondingly greater. Even if none of the urea was converted to ammonia in the creek or in the reservoir above Wagoner 2 ppm of ammonia would be added to 350 cfs in the reservoir. This flow or less occurred 38 percent of the time.

The foregoing examples illustrate only a few of the possible combinations of flow in Pryor Creek and Ft. Gibson Reservoir that could allow ammonia from Pryor Creek to interfere with chlorination to a free residual at the Wagoner water plant. A great many other possible combinations of adverse conditions could be computed.

Control of flow of Grand River at Pensacola Dam, especially for peaking power production, can cause flow past the mouth of Pryor Creek to fluctuate widely and rapidly. This can increase the difficulties of chlorination at Wagoner when ammonia is excessive. The concentration of ammonia at Wagoner at such times varies approximately inversely as the flow past Pryor Creek. When rapid variations in ammonia concentrations at Wagoner occur it is difficult to keep the chlorine dosage adjusted to meet the requirements of the changing ammonia content.

Although the paper mill wastes can add slightly to the chlorine demand of the water at Wagoner it is not probable that the effect of these wastes alone, in the absence of excessive ammonia, would ordinarily overtax the chlorination capacity available.

Taste and Odor

Taste and odor problems are reported to have been experienced in the Wagoner water supply, as previously noted. These problems are said to have been most difficult to combat when there was interference with attainment of a free chlorine residual.

It is difficult to evaluate the probable cause of taste and odor in water on the basis of description by others. The descriptions received are judged to indicate the cause at Wagoner most probably was algae in the reservoir. It is possible, however, that the Bestwall and National Gypsum paper mill wastes at times may have contributed to the taste and odor. The taste and odor caused by paper mill wastes are similar to some of those caused by algae.

The nitrogen wastes from the Deere plant can stimulate the production of algae in the reservoir by contributing to their nutrition. The reservoir naturally contains enough nitrogen (about 1 ppm) to support good algae populations. Any addition of nitrogen compounds can increase the probability of both frequency and magnitude of excessive algae production. It is not possible to reduce these probabilities to quantitative values in relation to nitrogen concentrations.

Fish Kills

The numerous fish kills in Ft. Gibson Reservoir at and below the mouth of Pryor Creek have been noted previously.

The information presented in Figures 25 through 28 suggest several probable causes of the death of fish, and an almost infinite variety of stream flows in Pryor Creek and Ft. Gibson Reservoir that could allow lethal conditions to develop in the reservoir.

Hydrogen sulfide is the most toxic of the probable lethal agents. It has been established that about 1 ppm is quickly lethal to essentially 100 percent of the fish exposed.

Figure 28 indicates that a flow of as little as 10 cfs in Pryor Creek, following prolonged absence of natural flow, can flush accumulated hydrogen sulfide into Ft. Gibson Reservoir to give a concentration of 1 ppm in 100 cfs flow in the reservoir. A flow of 40 cfs in Pryor Creek could produce 1 ppm concentration in 500 cfs. As little as 110 cfs in the creek can add 1 ppm of sulfide to 2,000 cfs in Ft. Gibson. Figures 6 and 29 show the frequencies with which these flows occurred during 1953-1956.

A flow of 500 cfs in Pryor Creek can add nearly 14 ppm sulfide to 100 cfs and over 3 ppm to 2,000 cfs flow in Ft. Gibson Reservoir.

Review of Figure 25 indicates that accumulated ammonia flushed out of Pryor Creek also can be toxic to fish in the reservoir. Since the 100 percent lethal level is about 25 ppm the range of flow conditions that will cause toxicity is considerably less than that which will cause sulfide toxicity.

A flow of 130 cfs in Pryor Creek is required to cause a 25 ppm ammonia concentration in 100 cfs in Ft. Gibson. About 155 cfs in the creek will produce 25 ppm in 500 cfs in the reservoir. With 2,000 cfs in Ft. Gibson a flow of 560 cfs is required in Pryor Creek.

At the low flow of 100 cfs in the reservoir, however, only 150 cfs in Pryor Creek will produce an ammonia concentration of 60 ppm in the reservoir.

Almost endless combinations of conditions, all within the realm of possibility, could be cited as examples.

A 5 day B.O.D. of 10 to 12 ppm, and possibly less, in Ft. Gibson Reservoir during the summer is almost certain to reduce the oxygen in the upper end of the reservoir to zero. A somewhat higher 5 day B.O.D., possibly in the range of 25 to 30 ppm, would be required to produce total oxygen depletion in the winter.

Figure 27 indicates that the accumulated B.O.D. in Pryor Creek could produce 12 ppm of 5 day B.O.D. with flows of 60 cfs in Pryor Creek and 100 cfs in Ft. Gibson Reservoir, of 105 cfs in the creek and 500 cfs in the reservoir, and of 210 cfs in the creek and 2,000 cfs in the reservoir.

A flow of 140 cfs in Pryor Creek could produce a concentration of about 60 ppm of B.O.D. in 100 cfs flow in the reservoir.

Here again an almost endless combination of adverse conditions could be cited.

Figure 27 shows the 30 day B.O.D. concentrations that could be produced in the reservoir. In general, levels are about 3 times the corresponding 5 day B.O.D.'s. In Ft. Gibson Reservoir, reaeration rates are extremely low, and detention times can be several weeks to a few months (Figure D-1). The long term B.O.D. effects can extend serious oxygen depletion following flushing of the creek, far down toward the lower end of the reservoir. As one example, 210 cfs in Pryor Creek could produce 100 ppm of 30 day B.O.D. in 500 cfs flow in the reservoir. If the slug of water containing this concentration of B.O.D. retained its identity in passing through the reservoir it could cause total depletion of D.O. all the way to the dam. The probability is, however, that longitudinal mixing would reduce the B.O.D. of the slug sufficiently to prevent total D.O. depletion as far as the dam.

The over-all probability is that hydrogen sulfide accumulated in Pryor Creek is apt to kill fish most frequently in the vicinity of the mouth of Pryor Creek. The sulfide should be oxidized fairly rapidly by the D.O. of the water from above Pryor Creek, and effects should not extend far below Pryor Creek.

Ammonia should kill fish less frequently than hydrogen sulfide, but the effects of ammonia would extend much farther downstream than those of the sulfide, possibly for many miles.

The effects of oxygen depletion caused by the oxygen demand of organic wastes usually would exhibit a delayed effect that might not kill fish for several miles below the creek. Below the point where D.O. drops to lethal levels, however, its effect could extend for many miles farther downstream.

When water from Ft. Gibson Reservoir intrudes into Pryor Creek on the surface some fish find their way up into the creek in the relatively clean surface layer. Anything that causes the surface layer to retract and be replaced by the polluted creek water can cause the fish to die in the lower end of the creek. If the dead fish then float into the reservoir they might be judged to be evidence of a fish kill in the reservoir itself. Several hydraulic conditions can cause retraction of the surface layer.

Any lowering of the level in the reservoir can cause retraction. High flows through the upper end of the reservoir can produce a backwater slope that will raise the surface elevation at the mouth of Pryor Creek. When flows are reduced by control at Pensacola Dam the surface elevation will drop. A similar condition can result from upstream winds that pile water up in the upper end of the reservoir, and then stop and allow the surface elevation to drop. Alternate raising and lowering of the entire reservoir level regularly results from normal operations at Ft. Gibson Dam. If any of these changes occurs rapidly fish can be killed in the surface layer of Pryor Creek.

Even a small increase in flow in Pryor Creek can cause retraction of the surface layer. An example of this was observed on September 17 during the field operations. Two sedimentation basins were dumped for cleaning at the GRDA steam plant. The total extra quantity of water discharged was 1.5 million gallons. Following this operation the relatively clear surface layer near the mouth of Pryor Creek was pushed downstream and a few fish were observed dying about a quarter of a mile above the mouth of the creek.

An analysis, similar to that in the section on water supply, has been made of the effects on fish life of protracted moderate to high flows in Pryor Creek which would carry the wastes to the reservoir without significant reduction. This analysis indicates that hydrogen sulfide and ammonia probably would not be harmful to fish under these conditions. The B.O.D. of the wastes could cause serious oxygen depletion.

Of the pollutional materials, the Bestwall and National Gypsum wastes are judged to be responsible for the hydrogen sulfide production and for most of the B.O.D. that could cause fish kills in the reservoir. The Deere wastes are the source of essentially all of the ammonia.

SUGGESTED LIMITS OF POLLUTION

The State agency or agencies responsible for pollution control in Ft. Gibson Reservoir should adopt objectives of water quality for Ft. Gibson Reservoir, and should establish limits on quantities of wastes that may be discharged from sources of pollution.

This section of the report offers suggestions regarding water quality objectives that may be desirable. It includes estimates of quantities of wastes that should not cause violation of the objectives. These suggestions are limited to those waste materials encountered during the field survey that were potentially harmful to existing water uses. Additional water quality objectives may be needed for protection against potential future pollution.

It is felt that much of the benefit of the intimate experience gained through direct contact with the Pryor Creek-Ft. Gibson Reservoir pollution problem during the survey would be lost to the responsible State agency if the suggested guide lines were not incorporated in this report.

Water Quality Considerations

Protection of 2 of the highest priority water uses should be assured for Ft. Gibson Reservoir by corrective measures at the sources of wastes. These uses are municipal water supply and recreation, including fishing.

Water Supply

The 2 principal water treatment problems that may recur at Wagoner are interference with chlorination to a free chlorine residual, and taste and odor. The nitrogen compounds discharged to the reservoir are involved in both of these problems.

Only ammonia, of the nitrogen compounds, should cause significant interference with chlorination. Ft. Gibson Reservoir water has a natural ammonia content of about 0.3 ppm, and a natural chlorine demand of about 3 to 5 ppm. It is reasonable to expect that the town may have to use moderately higher chlorine dosages a portion of the time to permit the needed use of the reservoir for disposal of limited ammonia waste.

The selection of a limiting objective for ammonia thus becomes a matter of judgment regarding a proper balance between the need of the town to avoid excessive chlorination costs and the need of the industry for a means of final waste disposal after reasonable reduction at the source.

Even those municipalities that must use water polluted with sewage rarely have to apply more than 10 to 12 ppm of chlorine to obtain a satisfactory safe free chlorine residual. Thus there is a precedent for suggesting that the chlorine demand of Ft. Gibson water should not exceed about 10 ppm.

The ratio of about 10 ppm of chlorine to 1 ppm of ammonia to accomplish oxidation of ammonia in many waters has been discussed previously. Experience at Wagoner indicates that approximately this ratio holds for Ft. Gibson water.

On this basis it is suggested that a limiting objective of 1 ppm for ammonia nitrogen in Ft. Gibson water be considered. Since the water naturally contains about 0.3 ppm of ammonia nitrogen, this means that any increase should not be more than 0.7 ppm.

A limiting objective for total nitrogen also should be considered to minimize algae growth and excessive taste and odor production. Very small concentrations of nitrates, as low as 0.3 ppm, can stimulate algae growth. Average nitrates in Ft. Gibson Reservoir during the survey were well below the 0.3 ppm level, ranging from about 0.08 to 0.11 ppm. The characteristic nitrogen cycle in water, previously described can lead to conversion of any of the 4 nitrogen compounds to any of the others, depending on the biological conditions prevailing. The only known method of limiting the concentration of any one form of nitrogen after entrance to water is to limit the total nitrogen.

There are no well established limiting criteria for the several forms of nitrogen in water that will assure control of excessive algae growth. It is possible that no universal criteria which will be applicable in all cases can be developed. It is necessary, however, in individual cases to reach a decision regarding limits, and the decision should be based on the soundest reasoning possible. It is proposed that the limiting nitrogen values in Ft. Gibson Reservoir be based on: the foregoing suggested limit for ammonia; the established fact that 0.3 ppm of nitrates is near the minimum that will stimulate the growth of algae; and the natural ratios of the several forms of nitrogen compounds found in the reservoir. The latter basis involves the assumption that biological forces in the reservoir will tend to bring the nitrogen wastes into equilibrium at the natural ratios, regardless of the form in which the nitrogen compounds are added.

The total nitrogen content of Ft. Gibson water averaged about 1.0 ppm, with approximately 0.6 ppm of organic nitrogen, 0.3 ppm of ammonia and 0.1 ppm of nitrates. Nitrites were negligible.

It is suggested that consideration be given to limiting nitrate nitrogen in Ft. Gibson Reservoir to 0.25 ppm, just below the level that will stimulate algae. If the natural ratios found in the reservoir hold, the total nitrogen permissible would be 10 times the nitrates, or 2.5 ppm. At biological equilibrium the ammonia then would be 0.3 of the total nitrogen or 0.75 ppm and organic nitrogen would be 1.5 ppm.

On this basis the suggested limiting objectives for nitrogen compounds to protect Ft. Gibson Reservoir for water supply use are that the total nitrogen added to the reservoir not be more than 1.5 ppm, and that not more than 0.7 ppm of this total be in the form of ammonia nitrogen, and not more than 0.25 ppm of the total as nitrate nitrogen.

In the preliminary report on this survey it was recommended that not more than 0.4 ppm total nitrogen be added to the reservoir. At that time it appeared that another plant that would produce nitrogen wastes would be constructed in the area. It was believed wise to reserve a portion of the nitrogen assimilative capacity of the reservoir to accommodate that plant. The new plant so far has failed to materialize. Unless nitrogen wastes from some source other than the present plants can be foreseen in the near future there appears to be little justification at this time for reserving a portion of the nitrogen assimilative capacity of the reservoir.

Fish Life

If the suggested limiting objectives for nitrogen to protect the reservoir for water supply use are adopted they will provide adequate protection against ammonia toxicity to fish.

A minimum D.O. of 5 ppm for protection of fish life is the objective most commonly used by stream pollution control authorities. Unless some compelling reason can be advanced for a lower minimum it does not appear wise to experiment by breaking well established precedent in a reservoir which is so popular with and productive for fishermen.

It is suggested that the D.O. objective be one which will not permit waste discharge to lower the D.O. below 5.0 ppm.

No need appears to exist in the present situation for limiting objectives for alkalinity and pH. If it should become evident that such objectives are needed it is suggested the limits be such as to prohibit any quantity or type of alkalinity that would raise the pH in the reservoir water above 8.6. Quantitative limits on alkalinity can best be established by titrations of reservoir water with the types of alkalinity involved.

Receiving Streams

Pryor Creek

Estimates have been made of the pollution that Pryor Creek can receive without developing accumulations of waste that would pose a threat to water quality in the reservoir. The daily quantities of B.O.D. and nitrogen permissible would be so small it is concluded that it would be practically impossible for the existing industrial plants to accomplish the needed reductions. It is suggested that consideration be given to elimination from the creek of the 3 wastes containing the major quantities of B.O.D. and nitrogen.

Grand River-Ft. Gibson Reservoir

The waste assimilative capacity of Ft. Gibson Reservoir is limited during periods of minimum flow. There are, on the other hand, many periods when higher flows provide relatively large assimilative capacities. Grand River is the most suitable stream in the immediate area for waste disposal.

For this reason subsequent discussion considers disposal of wastes in Ft. Gibson Reservoir only.

Design Stream Flows

Decisions regarding quantities of waste materials that may be discharged to a stream must take into consideration the minimum flow of the receiving stream.

Figure 29 shows the distribution of daily flows that have occurred in Grand River at Langley for the period January 1953, through October 1956. It shows that flows at Langley, below Pensacola Dam, were less than 100 cfs about 25 percent of the time.

The period covered by Figure 29 is relatively short for evaluation of natural stream flow trends, and it represents a period when stream flows in the area generally were low. Little would be gained at this time, however, from consideration of longer records and more representative periods of natural stream flow. The controlling factor in minimum stream flow into Ft. Gibson Reservoir is Pensacola Dam. Examination of the flow records in Table D-4, Appendix D, reveals that flows generally were low on week-ends even during months when there was sufficient storage in Grand Lake O' the Cherokees to permit high discharges through the generators on week days. There were only 5 months during the 4 years of record in Table D-4 when a minimum day's flow on one or more week-ends was not less than 100 cfs. Frequently flows for both Saturday and Sunday were near or below 100 cfs.

Such low week-end flows are characteristic of storage reservoirs operated for power production. They must be considered in selecting minimum design flows for waste disposal.

It is suggested that negotiations be undertaken with the Grand River Dam Authority regarding a firm committment on minimum flows below Pensacola Dam. Unless assurance can be obtained that GRDA will maintain minimum flows at some higher level than in the past it is suggested that 100 cfs be considered the minimum flow in Ft. Gibson Reservoir for waste disposal design.

Limits on Waste Discharges

Nitrogen Compounds

If the suggested limiting objective for nitrogen compounds be adopted, and if no greater minimum design flow than 100 cfs can be assured by GRDA, the limiting discharge of nitrogen wastes to Ft. Gibson Reservoir may be calculated.

These 2 considerations would require that discharge of total nitrogen to the reservoir not exceed 810 pounds per day, of which not more than 380 pounds shall be ammonia nitrogen.

For flows greater than 100 cfs nitrogen compounds discharged to the reservoir may be increased in direct proportion to the increase in stream flows.

Biochemical Oxygen Demand

Reductions in B.O.D. needed to assure maintenance of the suggested 5 ppm minimum D.O. can not be estimated so simply as can the limits on nitrogen compounds. The complex reasons for this were discussed in the sections on B.O.D. and D.O. in Ft. Gibson Reservoir. They are summarized below.

1. B.O.D. in the reservoir did not follow the usual course of reduction at a constant rate. Instead there was a continuing exertion of oxygen demand of about 0.5 ppm per day throughout the reservoir.

2. D.O. values as low as 5.0 and 5.7 ppm, representing saturation values of 55.3 and 63.2 percent were found on 2 of 4 samples collected above Pryor Creek.

3. Low D.O. values found at the upper end of Ft. Gibson Reservoir were caused by failure of Grand River to

recover from D.O. depletion in the bottom of Grand Lake O' the Cherokees. Experience elsewhere indicates that even lower D.O.'s than those found during the survey may occur above Pryor Creek.

4. Despite very low additions of B.O.D. to water in the reservoir by wastes from Pryor Creek the D.O. exhibited essentially no evidence of increase in passage through the reservoir. D.O. remained near 6.0 ppm throughout.

5. Failure of the D.O. to show appreciable recovery in the reservoir probably was caused by a combination of thermal stratification, which inhibited mixing from top to bottom, and the continuing exertion of 0.5 ppm of oxygen demand per day.

These conditions show that the reservoir has a very low capacity for assimilating oxygen demanding material. An additional complicating factor would be introduced if Markham Ferry Dam should be built. The new reservoir could reduce reaeration between Pensacola Dam and the upper end of Ft. Gibson Reservoir and allow water to enter the reservoir with even lower D.O. than that found during the survey.

In view of the poor oxygen resources of the reservoir and the uncertainties involved in attempting to compute a permissible B.O.D. loading of its waters by conventional means it is suggested that consideration be given to a requirement that the paper mills provide reductions in the 5 day B.O.D. of their wastes equivalent to that accomplished by the standard activated sludge sewage treatment process. This reasonable requirement is suggested for minimum discharges in the reservoir of 100 cfs. When flows are higher proportionally more B.O.D. may be discharged.

When both 5 day B.O.D. and nitrogen wastes are reduced to acceptable levels second stage B.O.D. should not cause any problem in the reservoir. For this reason no suggestions are made regarding reductions in 30 day B.O.D.

SUMMARY

Pryor Creek, in the vicinity of Pryor, Oklahoma, receives wastes from the Pryor sewage treatment plant, the John Deere and Company synthetic ammonia and urea plant, the Bestwall Gypsum Company paper mill, the National Gypsum Corporation paper mill, and the Grand River Dam Authority steam plant. The creek is dry above Pryor much of the time, permitting the wastes discharged to it to accumulate in the creek bed.

The creek flows into the upper end of Ft. Gibson Reservoir. This large reservoir serves as a source of water supply for Wagoner, Oklahoma, about half way down the reservoir, and for Muskogee, Oklahoma, at the dam. The reservoir yields abundant sport fish and is extremely popular for swimming, water skiing, and boating. Numerous recreational facilities dot its banks.

Difficulties in water treatment and with taste and odor have been experienced in the Wagoner water supply. The principal treatment difficulty has resulted from interference with chlorination of the water. Available evidence indicated that the interferring material quite probably was ammonia. Taste and odor appear to be of natural origin, but the problem of control of taste and odor has been intensified by the interference with proper chlorination. The Superintendent of Utilities at Wagoner has reported that many water consumers have lost confidence in the municipal supply and drink bottled water instead.

There has been only minor evidence of interference with chlorination at the Muskogee water plant.

Numerous fish kills have occurred in Ft. Gibson Reservoir below the mouth of Pryor Creek. Dying fish have been observed as far as 15 miles downstream at the Wagoner water plant. The fish kills generally appear to occur after a period of dry weather, with little or no natural flow in Pryor Creek, followed by rain which produces enough run-off to flush the accumulated wastes into the reservoir.

The Governor's Coordinating Committee on Pollution Control sponsored a study of pollution in Pryor Creek and Ft. Gibson Reservoir to determine the causes of the adverse effects of pollution and the steps necessary to correct the condition. Many Federal, State and local agencies, including those responsible for the sources of wastes, cooperated in the survey. The U. S. Public Health Service was assigned the responsibility for supervising the field operations and for preparing a report.

The field operations covered a period of about two months, from late in August to the latter part of October 1956. Samples were collected for examination from the sources of wastes, from Pryor Creek and from Ft. Gibson Reservoir all the way to the dam. Biological, chemical, physical and bacteriological examinations were conducted as considered necessary to a solution of the problem. Necessary hydrological data were obtained in the field and from records of the responsible agencies. A great deal of background information was assembled from a great many sources.

A preliminary report on the findings was submitted to the Technical Subcommittee of the Coordinating Committee. Comments on the preliminary report and a separate report by a consultant to the two paper mills, based on the data in the preliminary report, have been received. These comments and the consultant's report have been considered in preparation of this report. The conclusions in the following section are those of the U. S. Public Health Service authors of this report, and do not necessarily reflect the opinions of various individuals of the Technical Subcommittee.

CONCLUSIONS

1. The three principal sources of pollutional waste discharged to Pryor Creek are the plants of John Deere and Company, the Bestwall Gypsum Company, and the National Gypsum Corporation.

2. The principal deleterious wastes involved are ammonia and organic nitrogen (presumably urea) from the John Deere and Company plant, and organic oxygen demanding material from the Bestwall Gypsum Company and National Gypsum Corporation plants. The Bestwall plant produced approximately three times as much oxygen demanding material as did the National Gypsum plant.

3. The total quantities of waste materials accumulated in the creek were approximately 15 times the quantities discharged daily from the industrial plants. In addition, large quantities of hydrogen sulfide were formed in the creek by septic decomposition of organic wastes.

4. Analysis of the data show that when the accumulated wastes are flushed into the reservoir by a rise in the creek they can cause interference with proper chlorination at the Wagoner water plant which may result in a health hazard to the water consumers, and can interfere with control of taste and odor in the water supply.

5. The data also show that the flushing of the accumulated wastes into the reservoir can kill fish for many miles downstream. This can occur over an extremely wide range of stream flows in both Pryor Creek and in Ft. Gibson Reservoir.

6. Protracted moderate to high flows in Pryor Creek can carry the daily waste discharges directly to the reservoir with little or no reductions by natural purification. Under such circumstances problems similar to those following flushing of the creek can occur in water treatment and fish kills can result from the daily waste discharges without build up through accumulation in the creek.

7. Under either of the above conditions the nitrogen wastes from the John Deere and Company plant probably are the cause of water treatment difficulties at Wagoner. The nitrogen wastes also may

intensify the taste and odor problem both by stimulating the growth of algae and by interference with the method of chlorination that is most effective for taste and odor control.

8. The flushing of accumulated wastes into Ft. Gibson Reservoir can kill fish by creation of several lethal conditions. The most toxic material is hydrogen sulfide formed in the lower reaches of Pryor Creek by decomposition of the organic wastes from the Bestwall Gypsum Company and the National Gypsum Corporation plants. The oxygen demand of the organic materials from these two plants also can kill fish by depletion of the dissolved oxygen. The ammonia from the John Deere and Company plant can kill fish, but over a somewhat narrower range of flows in Pryor Creek and Ft. Gibson Reservoir than those which create conditions under which hydrogen sulfide is lethal.

   Direct transport of daily waste discharges directly to Ft. Gibson Reservoir by protracted moderate to high flows in Pryor Creek can kill fish by depletion of dissolved oxygen in the reservoir, but is not apt to kill them by hydrogen sulfide or ammonia.

9. During the survey the long detention of wastes in the creek permitted natural purification of the waste materials that reduced them by 90 to 95 percent at the mouth of the creek. In the absence of flushing action the materials entering the reservoir daily were only 5 to 10 percent of the quantities dicharged daily at their sources.

10. During the survey the quality of water in Ft. Gibson Reservoir generally was quite good for two reasons. First was that the daily quantities of waste discharged to the reservoir were small because of the high degree of natural purification occurring in the creek during the period. Second was that most of the water in the reservoir had passed the mouth of Pryor Creek at relatively high rates of flow and had received almost negligible concentrations of waste materials.

11. An exception to the generally high quality of water in the reservoir was the relatively low dissolved oxygen content. While not excessively low it was low enough to indicate that the dissolved oxygen resources of the reservoir are poor. Several factors are thought to contribute to this situation.

    a. Moderate to low dissolved oxygen in the water entering the upper end of the reservoir because of oxygen depletion in Grand Lake O' the Cherokees about 35 miles upstream.

    b. Low reaeration capacity of Ft. Gibson Reservoir because of depth, low velocities, and moderate stratification.

c. A continuing oxygen demand of the water that apparently approximately balances the reaeration rate.

12. Reductions in wastes at the three major sources that would permit safe discharge into Pryor Creek probably are impossible to achieve. These wastes should, after appropriate reductions, be discharged directly to Ft. Gibson Reservoir, or other means of final disposal should be sought.

13. Control of flow in Grand River by Pensacola Dam at Grand Lake O' the Cherokees is a key factor in decisions regarding quantities of wastes that may be discharged to Ft. Gibson Reservoir. Present operations regularly reduce week-end flows to about 100 cubic feet per second or less throughout the year.

14. Negotiations should be undertaken in an effort to obtain the assurance of the Grand River Dam Authority that it will not permit flows in Grand River below Pensacola Dam to fall below an agreed upon minimum at any time.

15. If an agreement on a minimum flow is achieved, that minimum would be used as the basis for waste treatment design. In the absence of such agreement the approximate week-end flows of record since Pensacola Dam was installed must be used for design purposes.

16. If waste treatment design must be based on existing week-end minimum flows it is estimated that nitrogen and organic wastes from the three major sources must be reduced about 90 percent below the quantities found in September 1956, to assure protection of water supplies and fish life in Ft. Gibson Reservoir.

17. If Markham Ferry Dam is built at the upper end of Ft. Gibson Reservoir it will further complicate the waste disposal problem. If the new dam is to be built the waste disposal problem should be reviewed to determine the probable impact of the new reservoir on waste disposal. Unless consideration is given to the problem in design of the penstock intakes Markham Ferry might cause a still greater, and possibly even disasterous, reduction in dissolved oxygen in Ft. Gibson Reservoir.

APPENDIX A

Table A-1

Pryor Sewage Treatment Plant
Station PS-1 Raw Sewage

Laboratory Data	Aug. 28	Aug. 29	Aug. 30	Average
pH	-	7.3	7.4	7.3
Phth.	-	0	0	0
Alkalinity				
M. O.	-	208	228	218
Chloride (ppm)	-	53	56.5	55
Total Solids (ppm)	734	703	624	687
Tot. Vol. Solids (ppm)	364	327	317	336
Tot. Fix. Solids (ppm)	370	376	307	351
Tot. Susp. Solids (ppm)	134	256	182	191
Susp. Vol. Solids (ppm)	102	220	138	153
Susp. Fix. Solids (ppm)	32	36	44	37
Ammonia N (ppm)	21.4	21.4	31.7	24.8
Nitrite N (ppm)	-	0.017	0	0.008
Nitrate N (ppm)	-	0.05	0.07	0.06
Organic N (ppm)	10.9	17.4	14.1	14.1
BOD, 5 day (ppm)	238	245	199	227
Color (ppm)	50	40	40	43

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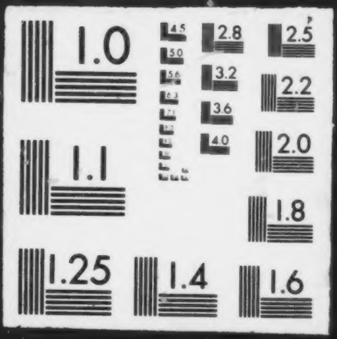
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5.0
5.6
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1.8
1.25
1.4
1.6

Table A-2

Pryor Sewage Treatment Plant
Station PS-1 Raw Sewage

Field Data	Aug. 28	Aug. 29	Aug. 30	Average
Flow (MGD)	0.442	0.460	0.435	0.446
Calculated Data				
Phth. (#/day)	-	0	0	0
Alkalinity				
M.O. (#/day)	-	797	825	811
Chloride (#/day)	-	203	205	204
Total Solids (#/day)	2700	2690	2260	2550
Tot.Vol.Solids (#/day)	1340	1250	1150	1250
Tot.Fix.Solids (#/day)	1360	1440	1110	1300
Tot.Susp.Solids(#/day)	493	900	659	711
Susp.Vol.Solids(#/day)	375	843	500	573
Susp.Fix.Solids(#/day)	118	137	159	138
Ammonia N (#/day)	79	82	115	92
Nitrite N (#/day)	-	0.065	0	0.033
Nitrate N (#/day)	-	0.19	0.25	0.22
Organic N (#/day)	40	67	51	53
BOD, 5 day (#/day)	675	538	720	645

Table A-3

Pryor Sewage Treatment Plant
Station PS-2 Primary Effluent

Laboratory Data	Aug. 28	Aug. 29	Aug. 30	Average
pH	-	72	73	72
Phth	-	0	0	0
Alkalinity				
M.O.	-	226	254	240
Chloride (ppm)	-	53	52.5	53
Total Solids (ppm)	657	630	563	617
Tot. Vol. Solids (ppm)	303	276	257	279
Tot. Fix. Solids (ppm)	354	354	306	338
Tot. Susp. Solids (ppm)	168	142	126	145
Susp. Vol. Solids (ppm)	130	116	106	117
Susp. Fix. Solids (ppm)	38	26	20	28
Ammonia N (ppm)	21.0	21.4	35.7	26.0
Nitrite N (ppm)	-	0.017	0	0.008
Nitrate N (ppm)	-	0.03	0.04	0.03
Organic N (ppm)	9.2	10.5	12.5	10.7
BOD, 5 day (ppm)	180	165	168	171
Color (ppm)	35	40	40	38

Table A-4

Pryor Sewage Treatment Plant
Station PS-2 Primary Effluent

Field Data	Aug. 28	Aug. 29	Aug. 30	Average
Flow (MGD)	0.442	0.460	0.435	0.446
Calculated Data				
Phth. (#/day)	--	0	0	0
Alkalinity				
M.O. (#/day)	-	866	919	892
Cr. Chloride (#/day)	-	203	190	197
Total Solids (#/day)	2420	2410	2040	2290
Tot.Vol.Solids (#/day)	1120	1060	930	1040
Tot.Fix.Solids (#/day)	1300	1350	1110	1250
Tot.Susp.Solids (#/day)	618	544	456	539
Susp.Vol.Solids (#/day)	478	444	384	435
Susp. Fix.Solids (#/day)	140	100	72	104
Ammonia N (#/day)	77	82	129	96
Nitrite N (#/day)	-	0.065	0	0.033
Nitrate N (#/day)	-	0.11	0.14	0.12
Organic N (#/day)	34	40	45	40
BOD, 5 day (#/day)	662	632	608	634

Table A-5

Pryor Sewage Treatment Plant
Station PS-3 Filter Effluent

Laboratory Data	Aug. 28	Aug. 29	Aug. 30	Average
pH	-	7.7	7.5	7.6
Phth	-	0	0	0
Alkalinity				
M.O.	-	138	162	150
Chloride (ppm)	-	46	49	47
Total Solids (ppm)	508	511	-	509
Tot. Vol. Solids (ppm)	185	174	-	179
Tot. Fix. Solids (ppm)	323	337	-	330
Tot. Susp. Solids (ppm)	65	56	-	60
Susp. Vol. Solids (ppm)	47	45	-	46
Susp. Fix. Solids (ppm)	18	11	-	14
Ammonia N (ppm)	12.2	12.6	18.2	14.3
Nitrite N (ppm)	-	0.171	0.282	0.226
Nitrate N (ppm)	-	3.20	4.20	3.70
Organic N (ppm)	5.0	6.7	7.1	6.3
BOD, 5 day (ppm)	25	23	27	25
Color (ppm)	40	40	45	42

Table A-6

Pryor Sewage Treatment Plant
Station PS-3 Filter Effluent

Field Data	Aug. 28	Aug. 29	Aug. 30	Average
Flow (MGD)	0.442	0.460	0.435	0.446
Calculated Data				
Phth (#/day)	-	0	0	0
Alkalinity				
M.O. (#/day)	-	529	5[illegible]	558
Chloride (#/day)	-	176	177	177
Total Solids (#/day)	1870	1960	-	1910
Tot.Vol.Solids (#/day)	680	670	-	670
Tot.Fix.Solids (#/day)	1190	1290	-	1240
Tot.Susp.Solids (#/day)	239	214	-	227
Susp.Vol.Solids (#/day)	173	172	-	173
Susp.Fix.Solids (#/day)	66	42	-	54
Ammonia N (#/day)	45	4[illegible]	66	53
Nitrite N (#/day)	-	0.65	1.02	0.84
Nitrate N (#/day)	-	12	15	14
Organic N (#/day)	18	26	2[illegible]	23
BOD, 5 day (#/day)	92	[illegible]	98	93

Table A-7

Pryor Sewage Treatment Plant
Station PS-4 Secondary Clarifier Effluent

Laboratory Data	Aug. 28	Aug. 29	Aug. 30	Average
pH	-	7.6	7.5	7.5
Phth.	-	0	0	0
Alkalinity				
M.O.	-	150	158	154
Chloride (ppm)	-	40	46	43
Total Solids (ppm)	492	448	452	464
Tot. Vol. Solids (ppm)	172	115	165	151
Tot. Fix. Solids (ppm)	320	333	287	313
Tot. Susp. Solids (ppm)	62	36	35	44
Susp. Vol. Solids (ppm)	51	32	30	37
Susp. Fix. Solids (ppm)	11	4	5	7
Ammonia N (ppm)	8.9	13.8	17.8	13.5
Nitrite N (ppm)	-	0.213	0.230	0.221
Nitrate N (ppm)	-	3.68	4.20	3.94
Organic N (ppm)	4.5	5.6	7.4	5.8
BOD, 5 day (ppm)	34	20	28	27
Color (ppm)	40	40	35	38
	Sept.13	Sept.18	Sept.25	Log.Mean
Coliforms (MPN/100ML.)	9,200,000	= >24,000,000	3,500,000	= >9,200,000

Table A-6

Pryor Sewage Treatment Plant
Station PS-4 Secondary Clarifier Effluent

Field Data	Aug. 28	Aug. 29	Aug. 30	Average
Flow (MGD)	0.442	0.460	0.435	0.446
Calculated Data				
Phth. (#/day)	-	0	0	0
Alkalinity				
M.O. (#/day)	-	575	572	573
Chloride (#/day)	-	176	167	172
Total Solids (#/day)	1810	1720	1640	1720
Tot.Vol.Solids (#/day)	630	440	600	560
Tot.Fix.Solids (#/day)	1180	1280	1040	1160
Tot.Susp.Solids(#/day)	228	138	127	164
Susp.Vol.Solids(#/day)	188	123	109	140
Susp.Fix.Solids(#/day)	40	15	18	24
Ammonia N (#/day)	33	53	64	50
Nitrite N (#/day)	-	0.62	0.63	0.62
Nitrate N (#/day)	-	14	15	15
Organic N (#/day)	17	21	27	22
BOD, 5 day (#/day)	125	77	101	101

Table A-9

Pryor Sewage Treatment Plant
Station PS-5 Lagoon Effluent

Laboratory Data	Aug. 28	Aug. 29	Aug. 30	Average
pH	-	8.5	8.7	8.6
Phth	-	-	-	-
Alkalinity				
M.O.	-	140	144	142
Chloride (ppm)	-	56	59	57
Total Solids (ppm)	459	431	424	438
Tot. Vol. Solids (ppm)	144	120	151	138
Tot. Fix. Solids (ppm)	315	311	273	300
Tot. Susp. Solids (ppm)	46	37	43	42
Susp. Vol. Solids (ppm)	37	35	38	37
Susp. Fix. Solids (ppm)	9	2	5	5
Ammonia N (ppm)	2.7	2.6	3.9	3.1
Nitrite N (ppm)	-	0.385	0.607	0.496
Nitrate N (ppm)	-	0.46	1.27	0.87
Organic N (ppm)	3.4	4.3	6.6	4.8
BOD, 5 day (ppm)	17	14	14	15
Color (ppm)	40	30	30	33
	Sept.13	Sept.18	Sept.25	Log.Mean
Coliforms (MPN/100ML.)	35,000	180,000	92,000	83,000

Table A-10

Pryor Sewage Treatment Plant
Station PS-5 Lagoon Effluent

Field Data	Aug. 28	Aug. 29	Aug. 30	Average
Flow (MGD)	0.431	0.453	0.420	0.435
Calculated Data				
Phth. (#/day)	-	0	0	0
Alkalinity				
M.O. (#/day)	-	528	504	516
Chloride (#/day)	-	211	206	209
Total Solids (#/day)	1650	1620	1480	1580
Tot.Vol.Solids (#/day)	520	450	530	500
Tot.Fix.Solids (#/day)	1130	1170	950	1080
Tot.Susp.Solids(#/day)	165	139	150	152
Susp.Vol.Solids(#/day)	133	132	133	133
Susp.Fix.Solids(#/day)	32	7	17	19
Ammonia N (#/day)	10	11	14	12
Nitrite N (#/day)	-	1.45	2.12	1.78
Nitrate N (#/day)	-	1.81	4.44	3.12
Organic N (#/day)	12	16	23	17
BOD, 5 day (#/day)	61	53	49	54

Table A-11

Deere and Co.
Station D-1   Lagoon Influent

Deere Field Data	Sept. 16	Sept. 18	Sept. 20	Sept. 23	Sept. 25	Sept. 27	Average
Temp. (°F)	137	135	138	138	139	136	137
pH	9.5	9.5	9.5	9.2	9.2	9.0	9.3
Conduct. (μ moh)	955	1630	1360	867	1100	4390	1717
D.O. (ppm)	-	-	-	-	-	-	-
NH_3 (ppm)	958	1440	476	267	300	460	650
Urea (ppm)	6500	14600	5900	3240	2960	7200	6740
Chromium (ppm)	0	0.44	0.02	0.09	0	0	0.09
PHS Laboratory Data							
pH	9.4	9.6	10.6	9.4	9.2	10.9	9.8
Phth. (ppm)	950	2005	2130	315	320	2062	1300
Alkalinity M.O. (ppm)	1600	3075	3665	605	750	3262	2160
Chloride (ppm)	27.5	36	54	5.5	6	22	25.2
Total Solids (ppm)	24950	21900	7833	3696	3382	9764	11910
Tot.Vol.Sol. (ppm)	24750	21620	5317	3232	2886	7038	10810
Tot.Fix.Sol. (ppm)	200	280	2516	374	496	2726	1100
Tot.Susp.Sol.(ppm)	864	466	374	136	274	2026	690
Susp.Vol.Sol.(ppm)	854	456	356	128	260	2008	677
Susp.Fix.Sol.(ppm)	10	10	18	8	14	18	13
Ammonia N (ppm)	942	1270	595	311	294	1020	739
Nitrite N (ppm)	0.019	0.081	0.055	0.008	0	0.038	0.033
Nitrate N (ppm)	0.16	0.21	0.17	0.64	0.12	0.24	0.26
Organic N (ppm)	1160	11470	2720	1550	1360	3180	3570
BOD, 5 day (ppm)	39	90	268	150	262	136	148
BOD, 10 day (ppm)	88	132	355	320	$\geq$345	168	$\geq$233
BOD, 20 day (ppm)	101[(a)]	166	$\geq$774	403	-	189	$\geq$327
BOD, 30 day (ppm)	132	180	$\geq$1170	482	-	253	$\geq$443
Color (ppm)	15	30	50	50	50	50	41
Oil (ppm)	-	272	274	305	761	140	350

(a) 21 day BOD

Table A-12

Deere and Co.
Station D-1 Lagoon Influent

Field Data	Sept. 16	Sept. 18	Sept. 20	Sept. 23	Sept. 25	Sept. 27	Average
Flow (MGD)	0.142	0.150[(b)]	0.138	0.185	0.111	0.173	0.150
Calculated Data							
Phth. (#/day)	1120	2510	2450	485	296	2970	1640
Alkalinity							
M.O. (#/day)	1890	3840	4240	932	695	4700	2720
Chloride (#/day)	32	45	62	8	6	32	31
Total Solids (#/day)	29400	27400	9010	5550	3130	14000	14700
Tot.Vol.Sol. (#/day)	29200	27000	6110	4980	2670	10100	13300
Tot.Fix.Sol. (#/day)	208	400	2900	570	460	3900	1400
Tot.Susp.Sol.(#/day)	1020	582	430	209	254	2920	902
Susp.Vol.Sol.(#/day)	1010	570	409	197	241	2890	886
Susp.Fix.Sol.(#/day)	10	12	21	12	13	30	16
Ammonia N (#/day)	1110	1590	684	479	272	1470	934
Nitrite N (#/day)	0.02	0.10	0.06	0.01	0	0.05	0.04
Nitrate N (#/day)	0.19	0.26	0.20	0.99	0.11	0.35	0.35
Organic N (#/day)	1370	14300	3150	2390	1260	4580	4510
BOD, 5 day (#/day)	46	112	308	231	187	196	180
BOD, 10 day (#/day)	104	165	406	493	≥319	242	≥288
BOD, 20 day (#/day)	119[(a)]	208	≥890	621	-	272	≥422
BOD, 30 day (#/day)	156	225	≥1350	742	-	364	≥567
Oil (#/day)	-	340	315	470	705	202	406

(a) 21 day BOD
(b) Average flow used because recorder stopped.

Table A-13

Deere and Co.
Station D-2 Lagoon Effluent

Deere Field Data	Sept. 16	Sept. 18	Sept. 20	Sept. 23	Sept. 25	Sept. 27	Average
Temp. (°F)	82	78	76	74	78	79	78
pH	8.0	8.0	8.4	8.3	8.3	8.2	8.2
Conduct. (μ mho)	16100	15440	15600	1[illegible]00	15450	15300	15610
D.O. (ppm)	1.29	0.9	1.0	2.1	1.1	1.7	1.3
NH_3 (ppm)	3428	3360	3410	3400	3410	3360	3390
Urea (ppm)	2350	3120	3100	2570	2420	2240	2630
Chromium (ppm)	0	0	0	0	0	0	0
PHS Laboratory Data							
pH	8.0	8.1	8.1	8.0	8.2	8.3	8.1
Phth. (ppm)	0	150	275	0	310	502	206
Alkalinity							
M.O. (ppm)	3745	4320	4790	3820	4230	4104	4170
Chloride (ppm)	39	37	37	32	34	38	36
Total Solids (ppm)	22930	13350	14560	14710	16350	12730	15770
Tot.Vol.Sol. (ppm)	10130	10560	11610	12010	13700	9820	11300
Tot.Fix.Sol. (ppm)	12800	2790	2950	2700	2650	2910	4470
Tot.Susp.Sol.(ppm)	112	118	50	30	18	496	137
Susp.Vol.Sol.(ppm)	112	114	48	30	18	496	136
Susp.Fix.Sol.(ppm)	0	4	2	0	0	0	1
Ammonia N (ppm)	2500	3190	3280	3260	2790	2830	2970
Nitrite N (ppm)	0.010	0	0	0.034	0.060	0.030	0.022
Nitrate N (ppm)	-	0.10	0.65	0.35	0.42	1.15	0.53
Organic N (ppm)	10500	1560	1860	1360	1230	1190	2950
BOD, 5 day (ppm)	11	7.3	38	32	≥137	80	≥51
BOD, 10 day (ppm)	-	22	47	39	>137	96	≥68
BOD, 20 day (ppm)	609(a)	63	≥348	101	-	192	≥263
BOD, 30 day (ppm)	1420	≥310	≥754	156	-	≥242	≥576
Color (ppm)	160	160	140	125	165	125	146
Phenol (ppm)	-	-	0.01	-	-	-	-
Cyanide (ppm)	-	-	0	-	-	-	-
Oil (ppm)	-	15.0	13.0	6.7	12.0	8.4	11.0

(a) 21 day BOD

Table A-14

Deere and Co.
Station D-2 Lagoon Effluent

Field Data	Sept. 16	Sept. 18	Sept. 20	Sept. 23	Sept. 25	Sept. 27	Average
Flow (MGD)	0.142	0.150(b)	0.138	0.185	0.111	0.173	0.150
Calculated Data							
Phth. (*/day)	0	188	316	0	287	723	252
Alkalinity							
M.O. (*/day)	4420	5400	5510	5880	3920	5910	5170
Chloride (*/day)	46	46	43	49	31	55	45
Total Solids (*/day)	27100	16700	16700	22700	15100	18300	19400
Tot.Vol.Sol. (*/day)	12000	13200	13300	18500	12700	14100	14000
Tot.Fix.Sol. (*/day)	15100	3500	3400	4200	2400	4200	5400
Tot.Susp.Sol.(*/day)	132	147	57	46	17	714	185
Susp.Vol.Sol.(*/day)	132	142	55	46	17	714	184
Susp.Fix.Sol.(*/day)	0	5	2	0	0	0	1
Ammonia N (*/day)	2950	3990	3770	5020	2580	4080	3730
Nitrite N (*/day)	0.01	0	0	0.06	0.06	0.04	0.03
Nitrate N (*/day)	-	0.12	0.75	0.54	0.39	1.66	0.69
Organic N (*/day)	12400	1950	2140	2090	1140	1710	3570
BOD, 5 day (*/day)	13	9	44	49	≥127	115	≥60
BOD, 10 day (*/day)	-	27	54	60	≥127	138	≥81
BOD, 20 day (*/day)	719(a)	79	≥400	156	-	276	≥326
BOD, 30 day (*/day)	1680	≥388	≥867	240	-	≥348	≥705
Oil (*/day)	-	19	15	10	11	12	13

(a) 21 day BOD
(b) Average Flow used because recorder stopped.

Table A-15

Bestwall Gypsum Co.
Station B-1 Lagoon Influent

Bestwall Gypsum Data	Sept. 5	Sept. 7	Sept. 11	Sept. 12	Sept. 14	Average
Temp. (°F)	101	104	107	104	106	104
pH	4.9	4.4	4.9	4.9	4.7	4.8
D.O. (ppm)	2.7	1.9	1.9	1.7	1.4	1.9
PHS Laboratory Data						
pH	5.6	4.8	5.4	5.5	4.9	5.2
Phth.	0	0	0	0	0	0
Alkalinity						
M.O.	30	24	28	36	34	30
Chloride (ppm)	35	27	35	27	35	32
Total Solids (ppm)	-	1489	1669	1723	1688	1642
Tot.Vol.Sol. (ppm)	-	875	935	1112	1045	992
Tot.Fix.Sol. (ppm)	-	614	734	611	643	650
Tot.Susp.Sol.(ppm)	-	140	356	290	298	271
Susp.Vol.Sol.(ppm)	-	122	186	180	196	171
Susp.Fix.Sol.(ppm)	-	18	170	110	102	100
Ammonia N (ppm)	1.7	1.7	3.3	6.9	3.3	3.4
Nitrite N (ppm)	0.021	0	0.010	0	0.010	0.008
Nitrate N (ppm)	0.11	0.03	0.05	0.08	0.20	0.09
Organic N (ppm)	8.7	3.1	5.7	5.0	5.9	5.7
BOD, 5 day (ppm)	325	411	518	441	548	449
BOD, 10 day (ppm)	-	-	654	716	668	679
BOD, 20 day (ppm)	-	-	686(A)	730	746	721
BOD, 30 day (ppm)	-	-	838	816	1040	898
Color (ppm)	90	90	20	60	60	64

(A) 21 day BOD

Table A-16

Bestwall Gypsum Co.
Station B-1 Lagoon Influent

Field Data	Sept. 5	Sept. 7	Sept. 11	Sept. 12	Sept. 14	Average
Flow (MCD)	1.43	1.60	1.41	1.40	1.61	1.49
Calculated Data						
Phth. (#/day)	0	0	0	0	0	0
Alkalinity						
M.O. (#/day)	357	319	330	421	456	377
Chloride (#/day)	417	359	413	316	469	395
Total Solids (#/day)	-	19800	19700	20200	22600	20570
Tot.Vol.Sol.(#/day)	-	11600	11000	13000	14000	12400
Tot.Fix.Sol.(#/day)	-	8200	8700	7200	8600	8170
Tot.Susp.Sol.(#/day)	-	1860	4200	3390	3990	3360
Susp.Vol.Sol.(#/day)	-	1620	2190	2100	2630	2140
Susp.Fix.Sol.(#/day)	-	240	2010	1290	1360	1220
Ammonia N (#/day)	20	23	39	81	44	41
Nitrite N (#/day)	0.25	0	0.12	0	0.13	0.10
Nitrate N (#/day)	1.31	0.40	0.59	0.94	2.7	1.19
Organic N (#/day)	104	41	67	58	79	70
BOD, 5 day (#/day)	3870	5470	6110	5160	7340	5590
BOD, 10 day (#/day)	-	-	7720	8380	8950	8350
BOD, 20 day (#/day)	-	-	8090 (A)	8540	10000	8880
BOD, 30 day (#/day)	-	-	9890	9550	13900	11110

(A) 21 Day BOD

Table A-17

Bestwall Gypsum Co.
Station B-2 Lagoon Effluent

Bestwall Gypsum Data	Sept. 5	Sept. 7	Sept. 11	Sept. 12	Sept 14	Average
Temp. (°F)	98	99	100	100	100	99
pH	5.0	4.5	4.8	4.8	4.7	4.8
D.O. (ppm)	[illegible]	1.5	1.1	1.1	1.2	1.3
PHS Laboratory Data						
pH	-	4.7	4.9	5.1	4.8	4.9
Phth. (ppm)	-	0	0	0	0	0
Alkalinity						
M.O. (ppm)	-	19	16	22	30	22
Chloride (ppm)	35	30	34.5	38.5	36	34.8
Total Solids (ppm)	-	1264	1605	1488	1463	1454
Tot.Vol.Sol. (ppm)	-	608	912	898	829	811
Tot.Fix.Sol. (ppm)	-	656	693	590	634	643
Tot.Susp.Sol.(ppm)	-	38	156	96	170	115
Susp.Vol.Sol.(ppm)	-	-	66	72	120	86
Susp.Fix.Sol.(ppm)	-	-	90	24	50	55
Ammonia N (ppm)	1.7	2.5	4.2	6.5	3.3	3.6
Nitrite N (ppm)	0	0	0.015	0	0	0.003
Nitrate N (ppm)	0.08	0.02	0.12	0.10	0.18	0.10
Organic N (ppm)	7.0	2.5	4.8	3.8	5.0	4.6
BOD, 5 day (ppm)	-	551	496	381	388	454
BOD, 10 day (ppm)	-	-	518	528	536	561
BOD, 20 day (ppm)	-	-	762(A)	592	660	671
BOD, 30 day (ppm)	-	-	970	734	1030	911
Color (ppm)	80	80	60	80	45	69

(A) 21 day BOD

Table A-18

Bestwall Gypsum Co.
Station B-2 Lagoon Effluent

Field Data	Sept. 5	Sept. 7	Sept. 11	Sept. 12	Sept. 14	Average
Flow (MGD)	1.43	1.60	1.41	1.40	1.61	1.49
Calculated Data						
Phth. (#/day)	-	0	0	0	0	0
Alkalinity						
M.O. (#/day)	-	253	189	257	402	275
Chloride (#/day)	416	399	407	450	482	431
Total Solids (#/day)	-	16800	18900	17400	19600	18180
Tot.Vol.Sol.(#/day)	-	8090	10700	10500	11100	10100
Tot Fix.Sol.(#/day)	-	8710	8200	6900	8500	8080
Tot.Susp.Sol.(#/day)	-	505	1840	1120	2280	1440
Susp.Vol.Sol.(#/day)	-	-	780	840	1610	1080
Susp.Fix.Sol.(#/day)	-	-	1060	280	670	670
Ammonia N (#/day)	20	33	50	76	44	45
Nitrite N (#/day)	0	0	0.15	0	0	0.03
Nitrate N (#/day)	0.95	0.27	1.42	1.40	2.41	1.29
Organic N (#/day)	83	33	57	44	67	57
BOD, 5 day (#/day)	-	4670	5850	4460	5200	5040
BOD, 10 day (#/day)	-	-	7290	6180	7180	6880
BOD, 20 day (#/day)	-	-	8990(A)	6930	8840	8250
BOD, 30 day (#/day)	-	-	11400	8590	13800	11260

(A) 21 day BOD

Table A-19

National Gypsum Co.
Station N-1 Lagoon Influent

National Gypsum Data	Sept. 5	Sept. [illegible]	Sept. 11	Sept. 12	Sept. 14	Average
Temp. (°C)	47	46	45	46	45	46
pH	4.7	4.1	4.6	4.4	4.6	4.5
D.O. (ppm)	4.5	4.3	3.8	4.0	3.9	4.1
PHS Laboratory Data						
pH	5.4	4.8	5.1	4.5	5.0	4.9
Phth. (ppm)	0	0	0	0	0	0
Alkalinity						
M.O. (ppm)	15	8	9	0	14	9
Chloride (ppm)	20	25	34.5	58.5	35	34.6
Total Solids (ppm)	1219	1232	1891	1747	2239	1666
Tot.Vol.Sol. (ppm)	659	520	943	963	1075	832
Tot.Fix.Sol. (ppm)	560	712	948	784	1164	834
Tot.Susp.Sol.(ppm)	32	50	128	138	240	118
Susp.Vol.Sol.(ppm)	28	-	124	126	216	123
Susp.Fix.Sol.(ppm)	4	-	4	12	24	11
Ammonia N (ppm)	0.8	3.3	4.2	2.9	1.7	2.6
Nitrite N (ppm)	0	0	0.013	0.008	0	0.004
Nitrate N (ppm)	0.04	0.19	0.09	0.11	0.12	0.11
Organic N (ppm)	6.2	0.6	4.8	3.2	4.5	3.9
BOD, 5 day (ppm)	253	260	541	380	385	364
BOD, 10 day (ppm)	-	-	643(C)	509	504	552
BOD, 20 day (ppm)	-	-	935(A)	345	600	627
BOD, 30 day (ppm)	-	-	1030	696	752	826
Color (ppm)	5	25	30	50	35	29

(A) 21 day BOD (C) 8 day BOD

Table A-20

National Gypsum Co.
Station N-1, Lagoon Influent

Field Data	Sept. 5	Sept. 7	Sept. 11	Sept. 12	Sept. 14	Average
Flow (MGD)	0.635	0.662	0.627	0.662	0.690	0.655
Calculated Data						
Phth. (#/day)	0	0	0	0	0	0
Alkalinity						
M.O. (#/day)	80	44	47	0	80	50
Chloride (#/day)	106	138	180	323	201	190
Total Solids (#/day)	6460	6800	9890	9640	12900	9140
Tot.Vol.Sol. (#/day)	3490	2870	4930	5310	6200	4560
Tot.Fix.Sol. (#/day)	2970	3930	4960	4330	6700	4580
Tot.Susp.Sol.(#/day)	169	276	669	762	1380	651
Susp.Vol.Sol.(#/day)	148	-	648	696	1240	683
Susp.Fix.Sol.(#/day)	21	-	21	66	140	62
Ammonia N (#/day)	4.4	18	22	16	10	14
Nitrite N (#/day)	0	0	0.07	0.04	0	0.02
Nitrate N (#/day)	0.21	1.05	0.47	0.61	0.69	0.61
Organic N (#/day)	33	3	25	18	26	21
BOD, 5 day (#/day)	1340	1440	2830	2100	2210	1980
BOD, 10 day (#/day)	-	-	3360	2810	2900	3020
BOD, 20 day (#/day)	-	-	4890(a)	-	3450	4170
BOD, 30 day (#/day)	-	-	5390	3840	4320	4520

(a) 21 day BOD

Table A-21

National Gypsum Co.
Station N-2 Lagoon Effluent

National Gypsum Data	Sept. 5	Sept. 7	Sept. 11	Sept. 12	Sept. 14	Average
Temp. (°C)	26	23	26	27	27	26
pH	6.2	5.4	6.0	5.6	5.3	5.7
D.O. (ppm)	6.0	5.5	4.3	4.1	4.2	4.8
PHS Laboratory Data						
pH	6.7	5.8	6.3	5.9	5.7	6.1
Phth. (ppm)	0	0	0	0	0	0
Alkalinity						
M.O. (ppm)	49	22	26	18	27	28
Chloride (ppm)	18	17	45	41.5	43	33
Total Solids (ppm)	1009	1221	1402	1687	1942	145[illegible]
Tot.Vol.Sol. (ppm)	443	532	641	682	873	674
Tot.Fix.Sol. (ppm)	566	689	761	805	1069	778
Tot.Susp.Sol.(ppm)	17	22	34	20	48	28
Susp.Vol.Sol.(ppm)	16	-	22	18	44	25
Susp.Fix.Sol.(ppm)	1	-	12	2	4	5
Ammonia N (ppm)	0.8	3.3	2.5	3.7	4.6	3.0
Nitrite N (ppm)	0	0	0.013	0.008	0	0.004
Nitrate N (ppm)	0.04	0.03	0.04	0.02	0.14	0.05
Organic N (ppm)	6.0	0.7	3.8	3.4	5.0	3.8
BOD, 5 day (ppm)	275	207	371	417	425	339
BOD, 10 day (ppm)	-	-	473(c)	552	514	513
BOD, 20 day (ppm)	-	-	674(a)	-	590	632
BOD, 30 day (ppm)	-	-	821	780	726	776
Color (ppm)	15	10	25	35	35	24

(a) 21 day BOD (c) 8 day BOD

Table A-22

National Gypsum Co.
Station N-2, Lagoon Effluent

Field Data	Sept. 5	Sept. 7	Sept. 11	Sept. 12	Sept. 14	Average
Flow (MGD)	0.635	0.662	0.627	0.662	0.690	0.655
Calculated Data						
Phth. (*/day)	0	0	0	0	0	0
Alkalinity						
M.O. (*/day)	260	121	136	99	155	154
Chloride (*/day)	95	149	183	229	247	181
Total Solids (*/day)	5350	6740	7330	9310	11200	7990
Tot.Vol.Sol. (*/day)	2350	2940	3350	4870	5000	3700
Tot.Fix.Sol. (*/day)	3000	3800	3980	4440	6200	4290
Tot.Susp.Sol.(*/day)	90	121	178	110	276	155
Susp.Vol.Sol.(*/day)	85	-	115	99	253	138
Susp.Fix.Sol.(*/day)	5	-	63	11	23	25
Ammonia N (*/day)	4.4	18	13	20	26	16
Nitrite N (*/day)	0	0	0.07	0.04	0	0.02
Nitrate N (*/day)	0.21	0.17	0.21	0.11	0.81	0.30
Organic N (*/day)	32	3.9	20	19	29	21
BOD, 5 day (*/day)	1460	1140	1940	2300	2440	1860
BOD, 10 day (*/day)	-	-	2470	3050	2960	2830
BOD, 20 day (*/day)	-	-	3530(a)	-	3390	3460
BOD, 30 day (*/day)	-	-	4290	4310	4170	4250

(a) 21 day BOD

Table A-23

GRDA Steam Plant
Station G-1, Plant Effluent

GRDA Data	Sept. 5	Sept. 6	Sept. 11	Sept. 12	Average
Temp. (°C)	36	34	31	32	33
pH	9.5	9.9	9.4	9.4	9.5
DO (ppm)	9.8	10.7	7.0	7.0	8.6
PHS Laboratory Data					
pH	9.1	9.6	-	9.2	9.3
Phth. (ppm)	19	30	-	20	23
Alkalinity					
M.O. (ppm)	109	140	-	110	120
Chloride (ppm)	39	39	35	30.5	36
Total Solids (ppm)	500	446	493	353	448
Tot.Vol.Sol. (ppm)	130	83	93	68	93
Tot.Fix.Sol. (ppm)	370	363	400	285	355
Tot.Susp.Sol. (ppm)	94	33	144	68	85
Susp.Vol.Sol. (ppm)	40	20	32	20	28
Susp.Fix.Sol. (ppm)	54	13	112	48	57
Ammonia N (ppm)	0.46	0.21	0	0	0.17
Nitrite N(ppm)	0.013	0.043	0.008	0	0.016
Nitrate N (ppm)	0.10	0.10	0.04	0.03	0.07
Organic N (ppm)	3.5	1.1	0.4	1.5	1.6
BOD, 5 day (ppm)	1.3	2.2	2.8	1.2	1.9
BOD, 10 day (ppm)	-	-	4.8	1.7	3.3
BOD, 20 day (ppm)	-	-	6.4(a)	4.8	5.6
BOD, 30 day (ppm)	-	-	6.4	5.5	6.0
Color (ppm)	5	1	15	5	7

(a) 21 day BOD

Table A-24

GRDA Steam Plant
Station G-1, Plant Effluent

Field Data	Sept. 5	Sept. 6	Sept. 11	Sept. 12	Average
Flow (MGD)	-	-	-	-	1.76(d)
DO (#/day)	144	157	103	103	127
Calculated Data					
Phth. (#/day)	279	441	-	294	338
Alkalinity					
M.O. (#/day)	1600	2060	-	1620	1760
Chloride (#/day)	573	573	514	448	527
Total Solids (#/day)	7350	6560	7250	5190	6590
Tot. Vol. Sol. (#/day)	1910	1220	1370	1000	1380
Tot. Fix. Sol. (#/day)	5440	5340	5880	4190	5210
Tot. Susp. Sol. (#/day)	1380	485	2120	1000	1250
Susp. Vol. Sol. (#/day)	587	294	470	294	410
Susp. Fix. Sol. (#/day)	793	191	1650	706	840
Dis. Vol. Sol. (#/day)					970
Ammonia N (#/day)	6.8	3.1	0	0	2.5
Nitrite N (#/day)	0.19	0.63	0.12	0	0.23
Nitrate N (#/day)	1.47	1.47	0.59	0.44	0.99
Organic N (#/day)	51	16	6	22	24
BOD, 5 day (#/day)	19	32	41	18	28
BOD, 10 day (#/day)	-	-	70	25	48
BOD, 20 day (#/day)	-	-	94(a)	70	82
BOD, 30 day (#/day)	-	-	94	81	88

(a) 21 day BOD

(d) 1.76 MGD is the average of flow measurements made on Sept. 7, 14 and 26 which were 1.57, 2.28 and 1.42 MGD respectively.

Table A-25

Sewage Plant Branch
U. S. Highway 69
Station S-0.7

Field Data	Sept. 5	Sept. 7	Sept. 10	Sept. 13	Sept. 18	Sept. 25	Average
Time (AM)	11:00	9:45	9:40	10:25	10:50	12:20 PM	
Temp. (°C)	26	26	22	23	23	22	23
pH	8.6	8.5	8.8	8.8	9.1	8.8	8.8
DO (ppm)	6.6	3.6	4.9	4.2	6.3	5.2	5.1
PHS Laboratory Data							
pH	8.9	-	9.1	9.3	9.6	9.3	9.2
Phth. (ppm)	19	22	42	28	47	27	31
Alkalinity							
M.O. (ppm)	140	70	134	140	175	144	134
Chloride (ppm)	55.5	60	61	65	61.5	57.7	6[illegible]
Ammonia N (ppm)	3.0	2.1	1.8	1.3	0	2.2	1.7
Nitrite N (ppm)	0.684	0.673	0.725	0.792	0.704	0.744	0.720
Nitrate N (ppm)	0.74	0.60	1.12	1.03	0.91	0.89	0.88
Organic N (ppm)	8.[illegible]	4.8	6.4	5.6	11.4	14.1	8.4
BOD, 5 day (ppm)	18	11	16	12	77	61	33
BOD, 10 day (ppm)	-	-	48	17	122	92	70
BOD, 20 day (ppm)	-	-	163(f)	50	≥200	111	≥116
BOD, 30 day (ppm)	-	-	103	71	≥200	142	≥129
Color (ppm)	10	10	40	40	75	50	37
Coliform (MPN/100Ml)	84,000	11,000	-	54,000	170,000	1,700,000	108,000(e)

(e) log mean

(f) 22 day BOD

Table A-26

Sewage Plant Branch
U. S. Highway 69
Station S-0.7

Field Data	Sept. 5	Sept. 7	Sept. 10	Sept. 13	Sept. 18	Sept. 25	Average
Flow (MGD)							0.435
Calculated Data							
DO (#/day)	24	13	18	15	23	19	19
Phth. (#/day)	69	80	152	162	171	98	112
Alkalinity							
M.O. (#/day)	508	254	486	508	635	523	486
Chloride (#/day)	201	218	221	236	223	209	218
Ammonia N (#/day)	10.9	7.6	6.5	4.7	0	8.0	6.3
Nitrite N (#/day)	2.5	2.4	2.6	2.6	2.6	2.7	2.6
Nitrate N (#/day)	2.7	2.2	4.1	3.7	3.3	3.2	3.2
Organic N (#/day)	29	17	23	20	41	51	30
BOD, 5 day (#/day)	65	40	65	44	280	221	119
BOD, 10 day (#/day)	-	-	174	62	443	334	253
BOD, 20day (#/day)	-	-	374(f)	182	≥726	403	≥421
BOD, 30 day (#/day)	-	-	374	258	≥726	515	≥468

(f) 22 day BOD

Table A-27

Pryor Creek above Deere & Co.
Station P-10.5

Field Data	Sept. 4	Sept. 6	Sept. 14	Sept. 19	Sept. 21	Sept. 24	Sept. 27	Average
Time (AM)	8:25	6:15	7:40	7:30	7:40	7:10	-	
Temp. (°C)	24	20	22	21	20	17	-	21
pH	7.5	7.4	7.4	7.3	7.6	7.3	-	7.4
DO (ppm)	5.6	3.8	4.3	3.7	4.6	3.8	-	4.3
Laboratory Data								
pH	-	7.6	7.6	7.8	8.3	8.0	8.2	7.9
Phth. (ppm)	0	0	0	0	10	0	10	3
Alkalinity								
M.O. (ppm)	180	175	18	205	210	180	174	163
Chloride (ppm)	57.5	63.5	61	64.5	67	61	59	62
Total Solids (ppm)	406	-	-	-	-	-	-	-
Tot.Vol.Sol. (ppm)	105	-	-	-	-	-	-	-
Tot.Fix.Sol. (ppm)	301	-	-	-	-	-	-	-
Tot.Susp.Sol. (ppm)	9	-	-	-	-	29	-	-
Susp.Vol.Sol. (ppm)	7	-	-	-	-	5	-	-
Susp.Fix.Sol. (ppm)	2	-	-	-	-	24	-	-
Ammonia N (ppm)	0.28	0.34	0.20	0.39	0.33	0.21	0.30	0.29
Nitrite N (ppm)	0	0.013	0	0	0	0.030	0	0.006
Nitrate N (ppm)	0.02	0.04	0.02	0.02	0.02	0.01	0.15	0.04
Organic N (ppm)	2.0	2.1	2.0	1.0	2.2	1.9	1.8	1.9
BOD, 5 day (ppm)	4.0	2.8	2.9	2.7	2.7	3.4	1.8	2.9
BOD, 10 day (ppm)	-	-	3.4	3.6	5.0	3.7	3.7	3.9

Table A-27 (Con't.)

Pryor Creek above Deere & Co.
Station P-10.5

	Sept. 4	Sept. 6	Sept. 14	Sept. 19	Sept. 21	Sept. 24	Sept. 27	Average
BOD, 20 day (ppm)	-	-	11	12	10	8.7	7.5	9.8
BOD, 30 day (ppm)	-	-	14	18	13	-	10	14
Color (ppm)	35	30	25	25	25	50	75	38
Phenol (ppm)	-	-	0.009	-	-	-	-	-
Cyanide (ppm)	-	-	0	-	-	-	-	-
Oil (ppm)	-	-	9.0	-	3.4	-	-	-
						Oct. 12		
Sulphide (ppm)	-	-	-	-	-	0	0	0

Table A-28

Pryor Creek Above Deere & Co.
Station P-10.5

Field Data	Sept. 4	Sept. 6	Sept. 14	Sept. 19	Sept. 21	Sept. 24	Sept. 27	Average
Flow (MGD)								4.35
Calculated Data								
DO (*/day)	20	14	16	13	17	14	-	16
Phth. (*/day)	0	0	0	0	36	0	36	10
Alkalinity								
M.O. (*/day)	653	635	65	744	762	653	632	592
Chloride (*/day)	209	230	221	234	243	221	214	225
Total Solids (*/day)	1470	-	-	-	-	-	-	-
Tot.Vol.Sol.(*/day)	380	-	-	-	-	-	-	-
Tot.Fix.Sol.(*/day)	1090	-	-	-	-	-	-	-
Tot.Susp.Sol.(*/day)	33	-	-	-	-	105	-	-
Susp.Vol.Sol.(*/day)	26	-	-	-	-	18	-	-
Susp.Fix.Sol.(*/day)	7	-	-	-	-	87	-	-
Ammonia N (*/day)	1.0	1.2	0.7	1.4	1.2	0.8	1.1	1.1
Nitrite N (*/day)	0	0.05	0	0	0	0.11	0	0.02
Nitrate N (*/day)	0.07	0.15	0.07	0.07	0.07	0.04	0.54	0.14
Organic N (*/day)	7.3	7.6	7.3	3.6	8.0	6.9	6.5	6.7
BOD, 5 day (*/day)	15	10	11	10	10	12	6.5	11
BOD, 10 day (*/day)	-	-	12	13	18	13	13	14
BOD, 20 day (*/day)	-	-	40	44	36	32	27	36
BOD, 30 day (*/day)	-	-	51	65	47	-	36	50
Oil (*/day)	-	-	0	-	12	-	-	-
Sulphide (*/day)	-	-	-	-	-	Oct.12 0	0	0

Table A-29

Pryor Creek Above Bestwall Gypsum Co.
Station P-8.6

Field Data	Sept. 4	Sept. 6	Sept. 14	Sept. 19	Sept. 21	Sept. 24	Sept. 27	Average
Time (AM)	9:05	7:15	8:20	8:00	8:15	-	7:40	
Temp (°C)	24	22	23	23	20	-	20	22
pH	8.2	88.5	8.3	8.3	8.4	-	9.0	8.4
DO (ppm)	7.0	0.5	6.4	0.0	6.0	-	0.0	3.3
Laboratory Data								
pH	-	8.1	7.9	8.0	8.[illegible]	8.1	8.3	8.1
Phth. (ppm)	0	0	0	0	0	90	234	46
Alkalinity M.O. (ppm)	1350	1495	106	1925	1700	2000	1874	1493
Chloride (ppm)	44.5	50	51	60	55	42.5	40	49
Total Solids (ppm)	3071	3178	1263	13170	73,000(g)	3616	4013	4720
Tot.Vol.Sol.(ppm)	1861	1974	29	1890	51,670(g)	2204	2470	1740
Tot.Fix.Sol.(ppm)	1210	1204	1234	11280	21,330(g)	1412	1543	2980
Tot.Susp.Sol.(ppm)	36	92	38	32	72	72	24	52
Susp.Vol.Sol.(ppm)	36	60	36	30	54	50	24	41
Susp.Fix.Sol.(ppm)	0	32	2	2	18	22	0	11
Ammonia N (ppm)	975	697	567	927	799	1010	825	829
Nitrite N (ppm)	7.91	5.03	4.75	0.95	3.83	0.75	1.88	3.59
Nitrate N (ppm)	0.09	0.36	1.02	0	0.04	0.13	0.13	0.25
Organic N (ppm)	230.6	68.6	46.2	4.3	75.6	1.7	3.6	61.5
BOD, 5 day (ppm)	52	6.4	20	8.9	6.3	9.0	13	17
BOD, 10 day (ppm)	-	-	24	17	9.2	20	20	18
BOD, 20 day (ppm)	-	-	-	30	12	24	26	23
BOD, 30 day (ppm)	-	-	27	-	19	20	70	39
Color (ppm)	90	100	100	120	120	75	200	115
Phenol (ppm)	-	-	0.008	-	-	-	-	-
Cyanide (ppm)	-	-	0	-	-	-	-	-
Oil (ppm)	-	-	0.9	-	17		-	-
Sulphide (ppm)	-	-	-	-	-	Oct.12 0	0	-

(g) This data is not included in average

Table A-30

Pryor Creek Above Bestwall Gypsum Co.
Station P-8.6

Field Data	Sept. 4	Sept. 6	Sept. 14	Sept. 19	Sept. 21	Sept. 24	Sept. 27	Average
Flow (MGD)								0.585
Calculated Data								
DO (#/day)	34	2	31	0	29	-	0	16
Phth. (#/day)	0	0	0	0	0	439	1140	226
Alkalinity M.O. (#/day)	6590	7300	517	9390	8300	9760	9150	7290
Chloride (#/day)	217	244	249	293	268	207	195	239
Total Solids (#/day)	15000	15500	6160	64300	356200(g)	17600	19600	23000
Tot.Vol.Sol.(#/day)	9100	9630	140	9200	252100(g)	10700	12100	8500
Tot.Fix.Sol.(#/day)	5900	5870	6020	55100	104100(g)	6900	7500	14500
Tot.Susp.Sol.(#/day)	176	449	185	156	351	351	117	255
Susp.Vol.Sol.(#/day)	176	293	175	146	263	244	117	202
Susp.Fix.Sol.(#/day)	0	156	10	10	88	107	0	53
Ammonia N (#/day)	4760	3400	2770	4520	3900	4930	4030	4040
Nitrite N (#/day)	39	25	23	4.7	19	3.7	9.2	18
Nitrate N (#/day)	0.44	1.76	4.98	0	0.20	0.63	0.63	1.2
Organic N (#/day)	1130	335	225	21	369	8	18	301
BOD, 5 day(#/day)	254	31	98	43	31	44	63	81
BOD, 10 day(#/day)	-	-	117	83	45	98	98	88
BOD, 20 day(#/day)	-	-	-	146	59	117	127	112
BOD, 30 day(#/day)	-	-	132	-	93	-	342	189
Oil (#/day)	-	-	4.4	-	83	-	-	-

(g) This data is not included in average

Table A-31

Pryor Creek Below Bestwall Gypsum Co.
Station P-6.4

Field Data	Sept. 4	Sept. 6	Sept. 20	Average
Time (AM)	9:40	6:50	8:30	--
Temp. (°C)	22	22	20	21
pH	6.4	6.5	6.3	6.4
DO (ppm)	0	0	0	0
Laboratory Data				
pH	-	6.9	6.3	6.6
Phth. (ppm)	0	0	0	0
Alkalinity				
M.O. (ppm)	330	310	265	302
Chloride (ppm)	34	45	18.5	32
Total Solids (ppm)	932	933	876	914
Tot.Vol.Sol. (ppm)	480	455	492	476
Tot.Fix.Sol. (ppm)	452	478	384	438
Tot.Susp.Sol. (ppm)	66	106	92	88
Susp.Vol.Sol. (ppm)	60	74	68	67
Susp.Fix.Sol. (ppm)	6	32	24	21
Ammonia N (ppm)	39.7	34.0	39.0	37.6
Nitrite N (ppm)	0	0.021	0	0.007
Nitrate N (ppm)	0.02	0.04	0.16	0.07
Organic N (ppm)	9.7	11.8	12.5	11.3
BOD, 5 day (ppm)	311	310	392	338
BOD, 10 day (ppm)	-	-	438	438
BOD, 20 day (ppm)	-	-	659	659
BOD, 30 day (ppm)	-	-	942	942
Color (ppm)	10	30	60	33

Table A-32

Pryor Creek Below Bestwall Gypsum Co.
Station P-6.4

Field Data	Sept. 4	Sept. 6	Sept. 20	Average
Flow (MGD)				2.07
Calculated Data				
DO (*/day)	0	0	0	0
Phth. (*/day)	0	0	0	0
Alkalinity M.O. (*/day)	5710	5360	4580	5220
Chloride (*/day)	588	779	320	562
Total Solids (*/day)	16100	16100	15200	15800
Tot.Vol.Sol. (*/day)	8300	7850	8500	8220
Tot.Fix.Sol. (*/day)	7800	8250	6700	7580
Tot.Susp.Sol.(*/day)	1140	1830	1590	1520
Susp.Vol.Sol.(*/day)	1040	1280	1180	1170
Susp.Fix.Sol.(*/day)	100	554	410	355
Ammonia N (*/day)	687	588	675	650
Nitrite N (*/day)	0	0.36	0	0.12
Nitrate N (*/day)	0.35	0.69	2.8	1.3
Organic N (*/day)	168	204	216	196
BOD, 5 day (*/day)	5380	5360	6780	5840
BOD, 10 day (*/day)	-	-	7580	7580
BOD, 20 day (*/day)	-	-	11400	11400
BOD, 30 day (*/day)	-	-	16300	16300

Table A-33

Pryor Creek Above National Gypsum Co.
Station P-5.6

Field Data	Sept. 4	Sept. 6	Sept. 12	Sept. 17	Sept. 19	Sept. 21	Sept. 27	Average
Time (AM)	10:40	8:00	8:00	8:10	8:20	8:55	8:00	-
Temp. (°C)	26	20	21	23	22	20	18	21
pH	7.0	7.3	7.2	7.3	6.9	6.9	6.9	7.1
DO (ppm)	0	0	0	0	0	0	0	0
Laboratory Data								
pH		7.6	7.7	7.6	7.3	7.8	7.4	7.6
Phth. (ppm)	0	0	0	0	0	0	0	0
Alkalinity								
M.O. (ppm)	390	405	341	295	370	400	340	363
Chloride (ppm)	24	26	40	37.5	20.5	43	18.5	30
Total Solids(ppm)	500	761	806	971	864	947	893	820
Tot.Vol.Sol.(ppm)	434	359	410	346	296	315	349	358
Tot.Fix.Sol.(ppm)	66	402	396	625	568	632	544	462
Tot.Susp.Sol.(ppm)	74	74	76	76	40	84	44	67
Susp.Vol.Sol.(ppm)	56	64	62	64	32	56	38	53
Susp.Fix.Sol.(ppm)	18	10	14	12	8	28	6	14
Ammonia N (ppm)	38.0	35.7	33.2	41.6	37.6	26.4	29.3	34.5
Nitrite N (ppm)	0	0.008	0	0	0.006	0	0	0.002
Nitrate N (ppm)	0.04	0.12	0.01	0.05	0.03	0.04	0.68	0.14
Organic N (ppm)	4.9	6.4	4.8	14.6	5.1	6.4	5.1	6.8
BOD, 5 day (ppm)	≥204	248	229	233	269	323	237	≥249
BOD, 10 day (ppm)	-	-	282	304	378	383	392	348
BOD, 20 day (ppm)	-	-	332	535(a)	431	-	-	433
BOD, 30 day (ppm)	-	-	-	661	677	648	-	662
Color (ppm)	50	60	70	50	90	60	165	78
Sulphide (ppm)	-	-	-	-	-	Oct.12 10	14	12

(a) 21 day BOD

Table A-34

Pryor Creek Above National Gypsum Co.
Station P-5.6

Field Data	Sept. 4	Sept. 6	Sept. 12	Sept. 17	Sept. 19	Sept. 21	Sept. 27	Average
Flow (MGD)								2.07
Calculated Data								
DO (#/day)	0	0	0	0	0	0	0	0
Phth.(#/day)	0	0	0	0	0	0	0	0
Alkalinity								
M.O.(#/day)	6750	7010	5900	5100	6400	6920	5880	6280
Chloride(#/day)	415	450	692	649	355	744	320	518
Total Solids(#/day)	8650	13200	13900	16800	14900	16400	15400	14200
Tot.Vol.Sol.(#/day)	7510	6200	7100	6000	5100	5500	6000	6200
Tot.Fix.Sol.(#/day)	1140	7000	6800	10800	9800	10900	9400	8000
Tot.Susp.Sol.(#/day)	1280	1280	1310	1310	692	1450	761	1150
Susp.Vol.Sol.(#/day)	969	1110	1070	1100	554	970	657	920
Susp.Fix.Sol.(#/day)	311	170	240	210	138	480	104	230
Ammonia N(#/day)	657	618	574	720	650	457	507	598
Nitrite N(#/day)	0	0.14	0	0	0.10	0	0	0.03
Nitrate N(#/day)	0.69	2.06	0.17	0.87	0.52	0.69	11.8	2.4
Organic N(#/day)	85	111	83	253	88	111	88	117
BOD, 5 day(#/day)	3530	4290	3960	4030	4650	5590	4100	4310
BOD, 10 day(#/day)	-	-	4880	5260	6540	6630	6780	6020
BOD, 20 day(#/day)	-	-	5740	9260(a)	7460	-	-	7490
BOD, 30 day(#/day)	-	-	-	11400	11700	11200	-	11400
Sulphide(#/day)	-	-	-	-	-	Oct.12 170	240	205

(a) 21 day BOD

Table A-35

Pryor Creek Above GRDA
Station P-5.4

Field Data	Sept. 4	Sept. 6	Sept. 17	Sept. 19	Sept. 21	Sept. 26	Sept. 27	Average
Time (AM)	11:10	8:35	8:35	8:45	8:35	9:15	8:30	-
Temp. (°C)	26	22	24	23	21	20	19	22
pH	6.7	6.9	6.9	6.9	6.9	6.5	6.9	6.8
DO (ppm)	0	0	0	0	0	0	0	0
Laboratory Data								
pH	-	7.4	7.5	7.2	7.3	7.1	7.0	7.2
Phth.(ppm)	0	0	0	0	0	0	0	0
Alkalinity								
M.O.(ppm)	330	305	280	290	335	280	272	299
Chloride(ppm)	39.5	31.5	38	34	42	38	22	35
Total Solids(ppm)	804	849	844	920	-	1106	1106	938
Tot.Vol.Sol.(ppm)	364	392	332	294	-	500	464	391
Tot.Fix.Sol.(ppm)	440	457	512	626	-	606	642	547
Tot.Susp.Sol.(ppm)	44	54	68	32	82	68	58	58
Susp.Vol.Sol.(ppm)	42	44	56	24	50	44	34	42
Susp.Fix.Sol.(ppm)	2	10	12	8	32	24	24	16
Ammonia N(ppm)	26.7	22.7	33.2	30.0	24.4	23.6	22.0	26.1
Nitrite N(ppm)	0	0	0	0	0	0	0	0
Nitrate N(ppm)	0.03	0.04	0.01	0.22	0.11	0.08	0.70	0.17
Organic N(ppm)	43	10.8	13.4	5.9	9.9	5.7	5.1	7.9
BOD, 5 day(ppm)	≥212	214	247	244	292	281	289	≥ 254
BOD, 10 day(ppm)	-	-	319	358	349	411	407	369
BOD, 20 day(ppm)	-	-	557(a)	397	380	475	490	460
BOD, 30 day(ppm)	-	-	623	433	565	521	557	540
Color(ppm)	10	20	35	60	80	50	50	44
Hex.Chromium(ppm)	-	-	(b)	0	0	0	0	0
Phenol(ppm)	-	-	-	-	Sept.20 0.15	-	-	-
Cyanide(ppm)	-	-	-	-	0	-	-	-
Sulphide(ppm)	-	-	-	-	-	Oct.12 12	14	13

(a) 21 day BOD

(b) Total Cr. equals 0.03 ppm on Sept. 17

Table A-36

Pryor Creek Above GRDA
Station P-5.4

Field Data	Sept. 4	Sept. 6	Sept. 17	Sept. 19	Sept. 21	Sept. 26	Sept. 27	Average
Flow (MGD)								2.73
Calculated Data								
DO (*/day)	0	0	0	0	0	0	0	0
Phth. (*/day)	0	0	0	0	0	0	0	0
Alkalinity								
M.O. (*/day)	7520	6950	6380	6610	7640	6380	6200	6810
Chloride (*/day)	900	718	866	775	958	866	502	798
Total Solids (*/day)	18300	19300	19200	21000	-	25200	25200	21400
Tot.Vol.Sol. (*/day)	8300	8900	7500	6700	-	11400	10600	8900
Tot.Fix.Sol. (*/day)	10000	10400	11700	14300	-	13800	14600	12500
Tot.Susp.Sol. (*/day)	1000	1230	1550	730	1870	1550	1320	1320
Susp.Vol.Sol. (*/day)	955	1000	1280	547	1140	1000	775	960
Susp.Fix.Sol. (*/day)	45	230	270	183	730	550	545	360
Ammonia N (*/day)	609	518	757	684	556	538	502	595
Nitrite N (*/day)	0	0	0	0	0	0	0	0
Nitrate N (*/day)	0.68	0.91	0.23	5.02	2.51	1.82	16.0	3.9
Organic N (*/day)	98	246	306	135	226	130	116	180
BOD, 5 day (*/day)	4830	4880	5630	5560	6660	6410	6590	5790
BOD, 10 day (*/day)	-	-	7270	8160	7960	9370	9280	8410
BOD, 20 day (*/day)	-	-	12700 (a)	9050	8660	10800	11200	10500
BOD, 30 day (*/day)	-	-	14200	9870	12900	11900	12700	12300
Sulphide (*/day)	-	-	-	-	-	Oct. 12 270	320	295
Hex. Chromium (*/day)	-	-	-	0	0	0	0	0

(a) 21 day BOD

Table A-37

Pryor Creek Below GRDA
Station B-4.8

Field Data	Sept. 5	Sept. 7	Sept. 10	Sept. 13	Sept. 18	Sept. 25	Sept. 28	Average
Time (AM)	12:00 N	10:25	8:40	9:25	10:20	11:30	8:30	-
Temp (°C)	30	24	22	26	25	24	23	25
pH	6.9	7.1	7.4	7.0	7.3	7.3	7.1	7.2
DO (ppm)	0	0	0	0	0	0	0	0
Laboratory Data								
pH	7.3	-	7.2	6.9	7.2	6.9	7.5	7.2
Phth. (ppm)	0	0	0	0	0	0	0	0
Alkalinity M.O. (ppm)	204	220	184	179	229	204	242	208
Chloride (ppm)	64	73.5	99	45	80.5	37.8	46.5	63.8
Total Solids (ppm)	661	672	699	670	512	783	439	634
Tot.Vol.Sol.(ppm)	234	226	247	252	246	274	148	233
Tot.Fix.Sol.(ppm)	427	446	452	418	266	509	291	401
Tot.Susp.Sol.(ppm)	24	32	50	78	202	45	64	71
Susp.Vol.Sol.(ppm)	18	-	50	44	176	31	60	63
Susp.Fix.Sol.(ppm)	6	-	0	34	26	14	4	14
Ammonia N (ppm)	13.8	15.1	17.0	14.7	15.9	12.2	13.0	14.5
Nitrite N (ppm)	0	0	0	0	0	0	0	0
Nitrate N (ppm)	0.04	0.03	0.08	0.03	0.03	0.10	0.05	0.05
Organic N (ppm)	8.5	2.8	2.9	3.1	3.4	3.6	3.4	3.9
BOD, 5 day (ppm)	127	125	82	164	95	127	238	137
BOD, 10 day (ppm)	-	-	143	209	124	145	290	182
BOD, 20 day (ppm)	-	-	-	219	188	149	-	185
BOD, 30 day (ppm)	-	-	338	240	270	386	403	327
Color (ppm)	45	30	30	50	30	75	75	48
Phenol (ppm)	-	-	0.23	-	(Sept.20) 0.11	-	-	-
Cyanide (ppm)	-	-	0	-	0	-	-	-
Sulphide (ppm)	-	-	-	-	-	1.8	(Oct.12) 6	4
Hex.Chromium (ppm)	-	-	-	(h)	(h)	0	0	-
Oil (ppm)	-	-	-	(Sept.14) 10.5	9.1	3.9	2.3	6.5
Coliform(MPN/100Ml)	$16x10^4$	$33x10^3$	-	$16x10^7$	$92x10^5$	$17x10^5$	-	$17x10^5$ (e)

(e) Log Mean

(h) Total Chromium was 0.01 ppm on Sept. 14 and 0.03 ppm on Sept. 18.

Table A-38

Pryor Creek Below GRDA
Station F-4.8

Field Data	Sept. 5	Sept. 7	Sept. 10	Sept. 13	Sept. 18	Sept. 25	Sept. 28	Average
Flow (MGD)								4.14
Calculated Data								
DO (#/day)	0	0	0	0	0	0	0	0
Phth. (#/day)	0	0	0	0	0	0	0	0
Alkalinity								
M.O. (#/day)	7040	7590	6350	6180	7900	7040	8350	7210
Chloride (#/day)	2210	2540	3420	1550	2780	1300	1600	2200
Total Solids (#/day)	22800	23200	24100	23100	17700	27000	15100	21900
Tot.Vol.Sol.(#/day)	8100	7800	8500	8700	8500	9450	5100	8020
Tot.Fix.Sol.(#/day)	14700	15400	15600	14400	9200	17600	10000	13800
Tot.Susp.Sol.(#/day)	828	1100	1720	2690	6970	1550	2210	2440
Susp.Vol.Sol.(#/day)	621	-	1720	1520	6070	1070	2070	2180
Susp.Fix.Sol.(#/day)	207	-	0	1170	900	480	140	483
Ammonia N (#/day)	476	521	586	507	549	421	138	457
Nitrite N (#/day)	0	0	0	0	0	0	0	0
Nitrate N (#/day)	1.4	1.0	2.8	1.0	1.0	3.4	1.7	1.8
Organic N (#/day)	293	97	100	107	117	124	114	136
BOD, 5 day(#/day)	4380	4310	2830	5660	3280	4380	8210	4720
BOD, 10 day(#/day)	-	-	4930	7210	4280	5000	10000	6280
BOD, 20 day(#/day)	-	-	-	7560	6490	5140	-	6400
BOD, 30 day(#/day)	-	-	11700	8280	9320	13300	13900	11300
Sulphide (#/day)	-	-	-	-	-	62	(Oct.12) 210	136
Oil (#/day)	-	-	-	Sept.14 360	310	150	79	220

Table A-39

Pryor Creek - Above Upper End of Backwater
Station P-4.0

Field Data	Sept. 4	Sept. 6	Sept. 11	Sept. 17	Sept. 20	Sept. 24	Sept. 27	Average
Time (AM)	12:45PM	11:10	9:15	9:10	9:00	-	9:30	-
Temp. (°C)	29	25	23	26	22	-	22	24
pH	7.1	7.3	7.4	7.1	7.5	-	6.7	7.2
DO (ppm)	0	0	0	0	0		0	0
Laboratory Data								
pH	-	7.6	7.8	7.5	7.5	7.3	7.3	7.5
Phth. (ppm)	0	0	0	0	0	0	0	0
Alkalinity								
M.O. (ppm)	300	275	227	245	165	230	308	250
Chloride (ppm)	45	85	86	88	50.5	98	98	79
Total Solids(ppm)	708	658	631	607	416	830	814	666
Tot.Vol.Sol.(ppm)	251	251	184	108	141	210	193	191
Tot.Fix.Sol.(ppm)	457	407	447	499	275	620	621	475
Tot.Susp.Sol.(ppm)	32	22	96	54	26	42	58	47
Susp.Vol.Sol.(ppm)	28	22	80	44	20	42	26	37
Susp.Fix.Sol.(ppm)	4	0	16	10	6	0	32	10
Ammonia N (ppm)	22.7	13.0	13.0	12.2	9.0	12.2	13.8	13.7
Nitrite N (ppm)	0	0	0	0	0	0.021	0	0.003
Nitrate N (ppm)	0.04	0.08	0.04	0.06	0.08	0.15	0.38	0.12
Organic N (ppm)	3.4	4.1	2.5	4.0	2.0	3.9	4.1	3.4
BOD, 5 day (ppm)	129	82	62	75	39	181	223	113
BOD, 10 day (ppm)	-	-	138	91	42	196	255	144
BOD, 20 day (ppm)	-	-	195(f)	202(a)	56	261	304	204
BOD, 30 day (ppm)	-	-	260	219	144	383	491	299
Color (ppm)	15	5	20	30	20	50	100	34
Sulphide (ppm)	-	-	-	-	-	Oct.12 38	24	31

(f) 22 day BOD (a) 21 day BOD

Table A-40

ryor Creek - Above Upper End of Backwater
Station P-4.0

Field Data	Sept. 4	Sept. 6	Sept. 11	Sept. 17	Sept. 20	Sept. 24	Sept. 27	Average
Flow (MGD)								4.14
Calculated Data								
DO (#/day)	0	0	0	0	0	0	0	0
Phth. (#/day)	0	0	0	0	0	0	0	0
Alkalinity M.O. (#/day)	10300	9490	7830	8450	5690	7930	10600	8610
Chloride (#/day)	1550	2930	2970	3040	1740	3380	3380	2710
Total Solids (#/day)	24400	22700	21700	20900	14400	28600	28100	23000
Tot.Vol.Sol. (#/day)	8700	8700	6300	3700	4900	7200	6700	6600
Tot.Fix.Sol. (#/day)	15700	14000	15400	17200	9500	21400	21400	16400
Tot.Susp.Sol. (#/day)	1100	759	3310	1860	897	1450	2000	1630
Susp.Vol.Sol. (#/day)	960	759	2760	1520	690	1450	900	1290
Susp.Fix.Sol. (#/day)	140	0	550	340	207	0	1100	340
Ammonia N (#/day)	783	449	449	421	310	421	476	473
Nitrite N (#/day)	0	0	0	0	0	0.72	0	0.1
Nitrate N (#/day)	1.4	2.8	1.4	2.1	2.8	5.2	13.1	4.1
Organic N (#/day)	117	141	8.6	114	69	135	141	115
BOD, 5 day (#/day)	4450	2830	2140	2590	1350	6240	7690	3900
BOD, 10 day (#/day)	-	-	4760	3140	1450	6760	8800	4980
BOD, 20 day (#/day)	-	-	6730(f)	6970(a)	1930	9000	10500	7030
BOD, 30 day (#/day)	-	-	8970	7560	4970	13200	16900	10300
Sulphide (#/day)	-	-	-	-	-	Oct. 12 1310	830	1070

(a) 21 day BOD

(f) 22 day BOD

Table A-41

Pryor Creek - Upper End of Backwater
Station P-3.1

Field Data	Sept. 4	Sept. 6	Sept. 11	Sept. 17	Sept. 20	Sept. 24	Sept. 27	Average
Time (AM)	12:20PM	10:25	8:20	9:35	8:45	-	9:10	-
Temp. (°C)	24	23	22	25	21	-	20	23
pH	7.3	7.4	7.4	7.3	7.7	-	7.5	7.4
DO (ppm)	0	0	0	0	0	-	0	0
Laboratory Data								
pH	-	8.1	8.1	7.9	7.8	8.2	7.7	8.0
Phth. (ppm)	0	0	0	0	0	20	0	3
Alkalinity M.O. (ppm)	360	345	289	335	330	350	340	336
Chloride (ppm)	75.5	77.5	70.5	78	69	75.5	90.5	77
Total Solids (ppm)	807	-	-	-		-	-	-
Tot.Vol.Sol.(ppm)	281	-	-	-		-	-	-
Tot.Fix.Sol.(ppm)	526	-	-	-		-	-	-
Tot.Susp.Sol. (ppm)	62	-	-	-		-	146	-
Susp.Vol.Sol.(ppm)	38	-	-	-		-	58	-
Susp.Fix.Sol. (ppm)	24	-	-	-		-	88	-
Ammonia N (ppm)	14.7	15.5	13.8	17.8	13.0	14.7	12.2	14.5
Nitrite N (ppm)	0	0.021	0	0	0	0.008	0	0.004
Nitrate N (ppm)	0.04	0.10	0.05	0.07	0.11	0.08	0.22	0.10
Organic N (ppm)	3.2	4.1	3.1	9.2	4.3	4.0	6.7	4.9
BOD, 5 day (ppm)	152	52	89	91	112	113	100	102
BOD, 10 day (ppm)	-	-	118	142	114	130	127	126
BOD, 20 day (ppm)	-	-	123(f)	159(a)	127	134	144	137
BOD, 30 day (ppm)	-	-	260	242	249	299	217	253
Color (ppm)	20	60	30	35	35	75	100	51
Sulphide (ppm)	-	-	-	-	-	Oct. 12 38	72	55

(a) 21 day BOD (f) 22 day BOD

Table A-42

Pryor Creek - Upper End of Backwater
Station P-3.1

Field Data	Sept. 4	Sept. 6	Sept. 11	Sept. 17	Sept. 20	Sept. 24	Sept. 27	Average
Flow (MGD)								4.14
Calculated Data								
DO (#/day)	0	0	0	0	0	0	0	0
Phth. (#/day)	0	0	0	0	0	0	0	0
Alkalinity								
M.O. (#/day)	12400	11900	9970	11600	11400	12100	11600	11600
Chloride (#/day)	2600	2670	2430	2690	2380	2600	3120	2640
Total Solids (#/day)	27800	-	-	-	-	-	-	-
Tot.Vol.Sol.(#/day)	9700	-	-	-	-	-	-	-
Tot.Fix.Sol.(#/day)	18100	-	-	-	-	-	-	-
Tot.Susp.Sol.(#/day)	2140	-	-	-	-	-	5040	-
Susp.Vol.Sol.(#/day)	1310	-	-	-	-	-	2000	-
Susp.Fix.Sol.(#/day)	830	-	-	-	-	-	3040	-
Ammonia N (#/day)	507	535	476	614	449	507	421	501
Nitrite N (#/day)	0	0.72	0	0	0	0.28	0	0.1
Nitrate N (#/day)	1.4	3.4	1.7	2.4	3.8	2.8	7.6	3.3
Organic N (#day)	110	141	107	317	148	138	231	170
BOD, 5 day (#/day)	5240	1860	3070	3140	3860	3900	3450	3500
BOD, 10 day(#/day)	-	-	4070	4900	3930	4480	4380	4350
BOD, 20 day(#/day)	-	-	4240	5490	4380	4620	4970	4740
BOD, 30 day(#/day)	-	-	8970	8350	8590	10300	7490	8740
Sulphide (#/day)	-	-	-	-	-	Oct. 12 1310	2490	1900

Table A-43

Pryer Creek - Middle Backwater
Station P-2.1

Field Data	Sept. 5	Sept. 7	Sept. 10	Sept. 13	Sept. 18	Sept. 25	Average
Time (AM)	9:05	8:10	7:55	7:35	8:15	9:00	-
Temp. (°C)	24	21	20	23	23	20	22
pH	7.4	7.6	7.5	7.5	7.6	7.3	7.5
DO (ppm)	0	0	0	0	0	0	0
Laboratory Data							
pH	-	-	7.8	8.1	8.3	7.9	8.0
Phth. (ppm)	0	0	0	0	15	0	2
Alkalinity M.O. (ppm)	345	370	300	275	413	325	338
Chloride (ppm)	96.5	73.5	97	84	72	85	85
Ammonia N (ppm)	13.0	19.5	15.5	14.7	15.9	8.3	14.5
Nitrite N (ppm)	0	0	0	0	0	0.008	0.001
Nitrate N (ppm)	0.04	0.03	0.04	0.05	0.01	0.10	0.05
Organic N (ppm)	5.9	2.1	9.4	3.4	5.3	3.1	4.9
BOD, 5 day (ppm)	91	87	58	71	61	63	72
BOD, 10 day (ppm)	-	-	95	79	80	116	92
BOD, 20 day (ppm)	-	-	155(f)	177	103	-	145
BOD, 30 day (ppm)	-	-	313	431	256	235	309
Color (ppm)	5	10	40	80	45	100	47
Sulphide (ppm)	-	-	-	-	Oct. 12 40	12	26

(f) 22 day BOD

Table A-44

Pryer Creek - Middle Backwater
Station P-2.1

Field Data	Sept. 5	Sept. 7	Sept. 10	Sept. 13	Sept. 18	Sept. 25	Average
Flow (MGD)							4.14
Calculated Data:							
DO (#/day)	0	0	0	0	0	0	0
Phth. (#/day)	0	0	0	0	517	0	86
Alkalinity							
M.O. (#/day)	11900	12800	10406	9490	14200	11200	11700
Chloride (#/day)	3330	2540	3350	2900	2480	2930	2920
Ammonia N (#/day)	448	673	535	507	549	286	500
Nitrite N (#/day)	0	0	0	0	0	0.28	0.05
Nitrate N (#/day)	1.4	1.0	1.4	1.7	0.3	3.4	1.5
Organic N (#/day)	204	72	324	117	183	107	168
BOD, 5 day (#/day)	3140	3000	2000	2450	2100	2170	2480
BOD, 10 day (#/day)	-	-	3280	2730	2760	4000	3190
BOD, 20 day (#/day)	-	-	5350	6110	3550	-	5000
BOD, 30 day (#/day)	-	-	10800	14900	8830	8110	10700
Sulphide (#/day)	-	-	-	-	Oct. 12 1380	410	895

Table A-45

Pryor Creek - Lower Backwater
Station P-1.0

Field Data	Sept. 5	Sept. 7	Sept. 10	Sept. 13	Sept. 18	Sept. 25	Average
Time (AM)	8:30	7:40	7:20	8:05	8:45	8:30	-
Temp. (°C)	24	22	20	23	24	21	22
pH	7.3	7.6	7.6	7.5	7.5	7.5	7.5
DO (ppm)	0	0	0	0	0	0	0
Laboratory Data							
pH	-	-	7.8	8.1	8.0	8.1	8.0
Phth. (ppm)	0	0	0	0	0	5	1
Alkalinity M.O. (ppm)	260	225	273	278	300	253	265
Chloride (ppm)	67	53	80.5	81	70.5	68	70
Ammonia N (ppm)	7.3	5.7	16.3	13.0	10.7	7.3	10.0
Nitrite N (ppm)	0	0	0	0	0	0.013	0.002
Nitrate N (ppm)	0.06	0.04	0.03	0.05	0	0.10	0.05
Organic N (ppm)	4.3	2.0	2.5	2.2	4.0	2.4	2.9
BOD, 5 day (ppm)	57	27	42	54	47	9.3	39
BOD, 10 day (ppm)	-	-	70	-	62	13	48
BOD, 20 day (ppm)	-	-	91(f)	86	66	-	81
BOD, 30 day (ppm)	-	-	174	91	131	15	103
Color (ppm)	50	30	50	40	35	50	42
Sulphide (ppm)	-	-	-	-	Oct. 12 28	12	20

(f) 22 day BOD

Table A-46

Pryer Creek - Lower Backwater
Station P-1.0

Field Data	Sept. 5	Sept. 7	Sept. 10	Sept. 13	Sept. 18	Sept. 25	Average
Flow (MGD)							4.14
Calculated Data							
DO (*/day)	0	0	0	0	0	0	0
Phth. (*/day)	0	0	0	0	0	172	29
Alkalinity							
M.O. (*/day)	8970	7760	9420	9590	10300	8730	9130
Chloride (*/day)	2310	1830	2780	2790	2430	2350	2410
Ammonia N (*/day)	252	197	562	449	369	252	347
Nitrite N (*/day)	0	0	0	0	0	0.45	0.07
Nitrate N (*/day)	2.1	1.4	0.7	1.7	0	3.4	1.5
OrganicN(*/day)	148	69	86	76	138	83	100
BOD, 5 day (*/day)	1970	931	1450	1860	1620	321	1360
BOD, 10 day (*/day)	-	-	2410	-	2140	449	1670
BOD, 20 day (*/day)	-	-	3140	2970	2280	-	2800
BOD, 30 day (*/day)	-	-	6000	3140	4520	518	3540
Sulphide (*/day)	-	-	-	-	Oct. 12 970	410	690

Table A-47

Pryor Creek - Mouth - Depth 12 feet
Station P-0.0

Field Data	Sept. 5	Sept. 7	Sept. 10	Sept. 13	Sept. 18	Sept. 25	Average
Time (AM)	9:50	7:00	7:00	8:30	9:15	7:30	-
Temp. (°C)	24	24	22	23	24	22	23
pH	7.6	7.5	8.0	7.7	7.6	7.6	7.7
DO (ppm)	0	6.8	0	0	1.0	0	1.3
Laboratory Data							
pH	-	-	8.0	7.8	7.7	7.7	7.8
Phth. (ppm)	0	0	0	0	0	0	0
Alkalinity							
M.O. (ppm)	225	94	262	210	143	187	187
Chloride (ppm)	59	18	64	60.5	21	38	43
Total Solids (ppm)	618	218	517	-	208	362	385
Tot.Vol.Sol.(ppm)	169	63	188	-	73	112	121
Tot.Fix.Sol.(ppm)	449	155	329	-	135	250	264
Tot.Susp.Sol.(ppm)	178	24	36	-	42	22	60
Susp.Vol.Sol.(ppm)	40	13	36	-	30	7	25
Susp.Fix.Sol.(ppm)	138	11	0	-	12	15	35
Ammonia N (ppm)	7.1	0.5	11.5	8.1	2.0	4.6	5.6
Nitrite N (ppm)	0	0	0	0	0	0.006	0.001
Nitrate N (ppm)	0.01	0.05	0.03	0.03	0.02	0.06	0.03
Organic N (ppm)	2.9	1.5	2.0	2.0	0	1.4	1.6
BOD, 5 day (ppm)	26	0.7	48	31	8.0	5.5	20
BOD, 10 day (ppm)	-	-	53	42	-	8.8	35
BOD, 20 day (ppm)	-	-	$56^{(f)}$	123	11	14	51
BOD, 30 day (ppm)	-	-	-	148	-	16	82
Color (ppm)	15	10	40	30	15	50	27
Sulphide (ppm)	-	-	-	-	{Oct 12 30}	10	20
Coliform(MPN/100Ml)	9500	790	-	$7x10^5$	$92x10^3$	$\cong 24x10^5$	$\cong 65x10^3$(e)

(f) 22 day BOD

(e) Log mean

Table A-48

Pryor Creek - Mouth - Depth 12 feet
Station P-0.0

Field Data	Sept. 5	Sept. 7	Sept. 10	Sept. 13	Sept. 18	Sept. 25	Average
Flow (MGD)							4.14
Calculated Data							
DO (*/day)	0	235	0	0	35	0	45
Phth. (*/day)	0	0	0	0	0	0	0
Alkalinity							
M.C. (*/day)	7760	3240	9040	7240	4930	6450	6440
Chloride (*/day)	2040	621	2210	2090	725	1310	1500
Total Solids (*/day)	21300	7520	17800	-	7180	12500	13300
Tot.Vol.Sol.(*/day)	5800	2170	6500	-	2520	3900	4200
Tot.Fix.Sol.(*/day)	15500	5350	11300	-	4660	8600	9100
Tot.Susp.Sol.(*/day)	6140	828	1240	-	1450	759	2080
Susp.Vol.Sol.(*/day)	1380	448	1240	-	1040	241	870
Susp.Fix.Sol.(*/day)	4760	380	0	-	410	518	1210
Ammonia N (*/day)	245	16	397	279	69	159	194
Nitrite N (*/day)	0	0	0	0	0	0.21	0.03
Nitrate N (*/day)	0.4	1.7	1.0	1.0	0.7	2.1	1.1
Organic N (*/day)	100	52	69	69	0	48	56
BOD, 5 day (*/day)	897	24	1660	1070	276	190	686
BOD, 10 day (*/day)	-	-	1829	1450	-	304	1190
BOD, 20 day (*/day)	-	-	1930(f)	4240	-	483	2220
BOD, 30 day (*/day)	-	-	-	5110	-	552	2830
Sulphide (*/day)	-	-	-	-	(Oct. 12) (1040)	350	695

(f) 22 day BOD

Table A-49

Pryor Creek - Mouth - Depth 6 feet
Station P-0.0

Field Data	Sept. 5	Sept. 7	Sept. 10	Sept. 13	Sept. 18	Sept. 25	Average
Time (AM)	9:55	7:10	7:15	8:45	9:15	7:45	-
Temp. (°C)	26	22	22	23	24	22	23
pH	7.7	7.6	7.4	7.8	7.6	7.7	7.6
DO (ppm)	6.1	6.1	5.8	5.0	0.15	4.8	4.7
Laboratory Data							
pH	-	-	7.9	7.9	7.8	8.1	7.9
Phth. (ppm)	0	0	0	0	0	1	0
Alkalinity							
M.O. (ppm)	100	184	96	100	141	108	121
Chloride (ppm)	17	18.5	16	23.5	19.5	14.5	18
Total Solids (ppm)	234	210	246	270	279	244	247
Tot.Vol.Sol.(ppm)	85	54	103	78	104	67	82
Tot.Fix.Sol.(ppm)	149	156	143	192	175	177	165
Tot.Susp.Sol.(ppm)	22	24	24	70	12	12	27
Susp.Vol.Sol.(ppm)	6	15	20	20	10	5	13
Susp.Fix.Sol.(ppm)	16	9	4	50	2	7	14
Ammonia N (ppm)	0.50	0.39	0.62	0.61	0.77	0.82	0.62
Nitrite N (ppm)	0	0	0	0	0	0	0
Nitrate N (ppm)	0.04	0.05	0.03	0.04	0.03	0.12	0.05
Organic N (ppm)	4.6	1.0	0.3	0.8	0	0.8	1.2
BOD, 5 day (ppm)	3.1	1.4	1.8	2.2	4.1	1.8	2.4
BOD, 10 day (ppm)	-	-	4.6	3.5	5.5	2.1	3.9
BOD, 20 day (ppm)	-	-	10.6$^{(f)}$	5.8	12.7	2.7	7.9
BOD, 30 day (ppm)	-	-	12	13	13	3.3	10
Color (ppm)	5	5	15	10	20	5	10
Sulphide (ppm)	-	-	-	-	{Oct.12} 0	≤0.1	≤0.05
Coliform(MPN/100ML)	1100	1300	-	$17x10^3$	$35x10^3$	$≤24x10^3$	≤7300$^{(e)}$

(f) 22 day BOD

(e) Log mean

Table A-50

Lake Survey - Mouth of Pryor Creek - Depth 12 feet
Station P-0.0

Field Data	Oct. 1	Oct. 3	Oct. 5	Oct. 9	Average
Time (AM)	7:10	12:00 N	-	-	-
Temp. (°F)	69.8	68.5	69	67.2	69
pH	7.4	7.5	7.5	7.6	7.5
DO (ppm)	0	0	0	-	0
Laboratory Data					
pH	7.6	7.7	7.7	7.6	7.7
Phth. (ppm)	0	0	0	0	0
Alkalinity					
M.O. (ppm)	246	290	300	199	259
Chloride (ppm)	47.5	72.5	71.5	-	64
Ammonia N (ppm)	6.50	0.42	7.75	4.93	4.90
Nitrite N (ppm)	0	0.004	0	0	0.001
Nitrate N (ppm)	0.07	0.15	0.06	0.05	0.08
Organic N (ppm)	1.5	2.3	1.6	2.0	1.9
BOD, 5 day (ppm)	40	65	65	32	51
BOD, 10 day (ppm)	-	69	84	-	76
BOD, 30 day (ppm)	≥63	82	118	42	≥76
Color (ppm)	75	100	125	75	94
Coliform, Surf., (MPN/100 Ml)	1700	130	3500	≥24000	≥2100 (e)

(e) Log mean

Table A-51

Lake Survey - Grand River - Depth 5 feet
Station G-40.0

Field Data	Oct. 1	Oct. 3	Oct. 5	Oct. 9	Average
Time (AM)	7:30	11:30	-	-	-
Temp. (°F)	72	72	71	69.2	71
pH	8.1	8.1	7.4	7.4	7.8
DO (ppm)	8.2	8.4	5.7	5.0	6.8
Laboratory Data					
pH	8.4	8.4	8.1	8.0	8.2
Phth. (ppm)	5	4	1	0	3
Alkalinity					
M.O. (ppm)	98	98	103	98	99
Chloride (ppm)	10	13.5	17.3	-	14
Ammonia N (ppm)	0.15	0.12	0.60	0.46	0.33
Nitrite N (ppm)	0.003	0.004	0.004	0.003	0.004
Nitrate N (ppm)	0.10	0.14	0.05	0.08	0.09
Organic N (ppm)	0.5	0.4	0.6	0.9	0.6
BOD, 5 day (ppm)	1.1	1.4	1.7	1.7	1.5
BOD, 30 day (ppm)	3.4	4.0	5.5	5.1	4.5
Color (ppm)	5	5	5	10	6
Coliform, Surf., (MPN/100 Ml)	240	33	920	350	220(e)

(e) Log mean

Table A-52

Lake Survey - Grand River - Depth 5 feet
Station G-37.7

Field Data	Oct. 1	Oct. 3	Oct. 5	Oct. 9	Average
Time (AM)	8:30	11:00	-	-	-
Temp. (°F)	70.2	73.2	72	69.5	71.2
pH	7.6	8.2	7.5	7.5	7.7
DO (ppm)	7.1	9.6	7.4	5.1	7.3
Laboratory Data					
pH	8.2	8.5	8.3	8.0	8.3
Phth. (ppm)	2	5	3	0	3
Alkalinity					
M.O. (ppm)	94	97	102	100	98
Chloride (ppm)	12.5	14	16.5	-	14
Ammonia N (ppm)	0.18	0.13	0.15	0.59	0.26
Nitrite N (ppm)	0	0.004	0	0	0.001
Nitrate N (ppm)	0.07	0.14	0.07	0.05	0.08
Organic N (ppm)	0.4	0.4	0.6	0.8	0.6
BOD, 5 day (ppm)	1.0	1.7	1.5	1.8	1.5
BOD, 30 day (ppm)	3.3	6.5	4.2	5.2	4.8
Color (ppm)	5	5	10	15	9
Coliform, Surf., (MPN/100 Ml)	49	23	33	140	48(a)

(a) Log mean

Table A-53

Lake Survey - Grand River - Depth 15 feet
Station G-37.7

Field Data	Oct. 1	Oct. 3	Oct. 5	Oct. 9	Average
Time (AM)	-	-	-		
Temp. (°F)	70.2	71	71.7	69.5	70.6
pH	7.5	8.0	7.4	7.3	7.6
DO (ppm)	6.8	3.8	4.3	4.9	5.0
Laboratory Data					
pH	8.1	8.0	8.0	8.1	8.1
Phth. (ppm)	1	0	0	1	1
Alkalinity					
M.O. (ppm)	97	103	103	101	101
Chloride (ppm)	12	13	50.7	-	25
Ammonia N (ppm)	0.11	0.44	0.34	0.46	0.34
Nitrite N (ppm)	0	0.009	0.004	0	0.003
Nitrate N (ppm)	0.07	0.14	0.05	0.10	0.09
Organic N (ppm)	0.6	0.5	0.7	0.9	0.7
BOD, 5 day (ppm)	1.3	1.4	1.7	1.6	1.5
BOD, 30 day (ppm)	3.6	2.6	4.5	5.0	3.9
Color (ppm)	5	10	5	10	8

Table A-54

Lake Survey - Grand River - Depth 5 feet
Station G-35.2

Field Data	Oct. 1	Oct. 3	Oct. 5	Oct. 9	Average
Time (AM)	9:30	7:15	-	-	-
Temp. (°F)	72.0	71.5	72.3	69.5	71.4
pH	7.7	7.7	7.5	7.5	7.6
DO (ppm)	7.50	7.78	8.30	5.73	7.3
Laboratory Data					
pH	8.3	8.3	8.5	8.0	8.3
Phth. (ppm)	3	4	4	0	3
Alkalinity					
M.O. (ppm)	93	96	99	95	96
Chloride (ppm)	16	16	17.8	-	16
Ammonia N (ppm)	0.28	0.23	0.18	0.46	0.29
Nitrite N (ppm)	0	0.009	0.004	0	0.003
Nitrate N (ppm)	0.06	0.11	0.07	0.02	0.07
Organic N (ppm)	0.5	0.5	0.5	0.7	0.6
BOD, 5 day (ppm)	1.5	1.7	1.8	1.4	1.6
BOD, 30 day (ppm)	4.1	3.2	4.2	3.7	3.8
Color (ppm)	5	5	15	5	8
Coliform, Surf., (MPN/100Ml)	-	130	49	220	110(e)

(e) Log mean

Table A-55

Lake Survey - Grand River - Depth 18 feet
Station G-35.2

Field Data	Oct. 1	Oct. 3	Oct. 5	Oct. 9	Average
Time (AM)	-	-	-	-	-
Temp. (°F)	71.0	70.5	71.5	69.7	70.7
pH	7.4	7.7	7.3	7.3	7.4
DO (ppm)	5.55	5.44	2.80	5.50	4.8
Laboratory Data					
pH	7.9	8.0	7.9	8.0	8.0
Phth. (ppm)	0	0	0	0	0
Alkalinity					
M.O. (Ppm)	97	100	102	96	99
Chloride (ppm)	15.5	17	19.7	-	17
Ammonia N (ppm)	0.12	0.41	0.33	0.46	0.33
Nitrite N (ppm)	0	0.006	0.004	0	0.003
Nitrate N (ppm)	0.05	0.14	0.06	0.07	0.08
Organic N (ppm)	0.5	0.6	0.7	0.6	0.6
BOD, 5 day (ppm)	1.2	1.7	1.9	1.6	1.6
BOD, 30 day (ppm)	4.0	4.0	4.8	3.8	4.2
Color (ppm)	5	5	10	15	9

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Table A-56

Lake Survey-Grand River-Depth 5 Ft.
Station G-31.9

Field Data	Oct. 1	Oct. 3	Oct. 5	Oct. 9	Average
Time (AM)	11:00	7:45	-	-	-
Temp. (°F)	71.6	72.0	70.8	69.8	71.1
pH	7.7	7.8	7.5	7.5	7.6
DO (ppm)	6.5	6.7	5.9	5.80	6.2
Laboratory Data					
pH	8.2	8.3	8.1	8.1	8.2
Phth. (ppm)	3	3	2	1	2
Alkalinity					
M.O. (ppm)	100	100	102	97	100
Chloride (ppm)	17	16.5	17.	-	17
Ammonia N (ppm)	0.38	0.23	0.39	0.46	0.36
Nitrite N (ppm)	0.003	0.006	0.013	0.013	0.009
Nitrate N (ppm)	0.04	0.13	0.08	0.06	0.08
Organic N (ppm)	0.5	0.5	0.7	0.7	0.6
BOD, 5 day (ppm)	0.8	1.7	1.6	1.3	1.4
BOD, 30 day (ppm)	3.8	4.6	4.1	3.6	4.0
Color (ppm)	5	5	15	5	8
Coliform, Surface, ($\frac{MPN}{100\ ml}$)	-	49	33	79	50 (e)

(e) Logarithmic Mean

Table A-57

Lake Survey - Grand River - Depth 18 feet
Station G-31.9

Field Data	Oct. 1	Oct. 3	Oct. 5	Oct. 9	Average
Time (AM)	-	-	-	-	-
Temp. (°F)	71.1	71.8	70.8	69.7	70.8
pH	7.7	7.6	7.3	7.5	7.5
DO (ppm)	6.15	5.5	5.2	5.88	5.7
Laboratory Data					
pH	8.1	8.2	8.0	8.1	8.1
Phth. (ppm)	2	2	0	1	1
Alkalinity					
M.O. (ppm)	101	98	100	99	100
Chloride (ppm)	17	17.5	17	-	17
Ammonia N (ppm)	0.35	0.25	0.39	0.42	0.35
Nitrite N (ppm)	0	0.006	0.011	0.013	0.008
Nitrate N (ppm)	0.05	0.12	0.07	0.07	0.08
Organic N (ppm)	0.5	0.6	0.5	0.7	0.6
BOD, 5 day (ppm)	0.9	1.6	1.4	0.9	1.2
BOD, 30 day (ppm)	4.0	4.4	4.7	3.1	4.1
Color (ppm)	5	5	15	5	8

Table A-58

Lake Survey - Grand River - Depth 32 feet
Station G-31.9

Field Data	Oct. 1	Oct. 3	Oct. 5	Oct. 9	Average
Time (AM)	-	-	-	-	-
Temp. (°F)	70.9	71.3	70.7	70.0	70.7
pH	7.5	7.5	-	7.4	7.5
DO (ppm)	5.5	5.0	2.8	5.82	4.8
Laboratory Data					
pH	7.9	8.0	7.9	8.0	8.0
Phth. (ppm)	0	0	0	0	0
Alkalinity					
M.O. (ppm)	103	98	102	98	100
Chloride (ppm)	18	17.5	17	-	18
Ammonia N (ppm)	0.37	0.35	0.47	0.50	0.42
Nitrite N (ppm)	0	0.009	0.015	0.013	0.009
Nitrate N (ppm)	0.05	0.12	0.06	0.08	0.08
Organic N (ppm)	1.0	0.7	0.5	0.7	0.7
BOD, 5 day (ppm)	1.0	1.6	1.4	1.4	1.3
BOD, 30 day (ppm)	4.0	5.2	4.8	3.8	4.5
Color (ppm)	5	5	15	10	8

Table A-59

Lake Survey - Grand River - Depth 5 feet
Station G-28.8

Field Data	Oct. 1	Oct. 3	Oct. 5	Oct. 9	Average
Time (AM)	12:00 N	8:30	-	-	-
Temp. (°F)	70.8	72.0	70.9	69.4	70.8
pH	7.7	7.7	7.5	7.5	7.6
DO (ppm)	7.7	8.25	6.8	7.24	7.5
Laboratory Data					
pH	8.4	8.5	8.2	8.2	8.3
Phth. (ppm)	5	5	2	2	4
Alkalinity					
M.O. (ppm)	101	104	101	99	101
Chloride (ppm)	14	14.5	15.5	-	15
Ammonia N (ppm)	0.18	0.25	0.23	0.31	0.24
Nitrite N (ppm)	0.013	0.015	0.018	0.018	0.016
Nitrate N (ppm)	0.07	0.11	0.11	0.05	0.09
Organic N (ppm)	0.5	0.6	0.6	0.8	0.6
BOD, 5 day (ppm)	1.0	2.2	1.4	1.8	1.6
BOD, 20 day (ppm)	4.4	5.3	4.2	4.3	4.6
Color (ppm)	5	5	20	10	10
Coliform, Surf., (MPN/100 Ml)	-	23	33	170	50(e)

(e) Log mean

Table A-60

Lake Survey - Grand River - Depth 18 feet
Station G-28.8

Field Data	Oct. 1	Oct. 3	Oct. 5	Oct. 9	Average
Time (AM)	-	-	-	-	-
Temp. (°F)	70.2	71.0	70.9	69.2	70.3
pH	7.7	7.6	7.5	7.5	7.6
DO (ppm)	7.15	6.5	6.4	6.93	6.7
Laboratory Data					
pH	8.2	8.2	8.2	8.2	8.2
Phth. (ppm)	4	3	2	3	3
Alkalinity					
M.O. (ppm)	106	106	100	101	103
Chloride (ppm)	14	13.5	16	-	14
Ammonia N (ppm)	0.33	0.21	0.28	0.35	0.29
Nitrite N (ppm)	0.011	0.020	0.026	0.018	0.019
Nitrate N (ppm)	0.07	0.14	0.08	0.08	0.09
Organic N (ppm)	0.5	0.5	0.5	0.8	0.6
BOD, 5 day (ppm)	-	-	1.6	1.5	1.6
BOD, 30 day (ppm)	4.8	-	4.2	4.4	4.5
Color (ppm)	5	10	20	5	10

Table A-61

Lake Survey-Grand River-Depth 32 Ft, Station G-28.8

Field Data	Oct. 1	Oct. 3	Oct. 5	Oct. 9	Average
Time (AM)	-	-	-	-	-
Temp. (°F)	70.2	70.5	70.5	69.0	70.0
pH	7.7	7.7	7.4	7.3	7.5
DO (ppm)	6.15	5.7	3.9	6.65	5.6
Laboratory Data					
pH	8.1	8.0	8.0	8.2	8.1
Phth. (ppm)	2	0	0	2	1
Alkalinity					
M.O.(ppm)	105	104	103	100	103
Chloride (ppm)	15.5	14.5	16	-	15
Ammonia N (ppm)	0.19	0.43	0.42	0.35	0.35
Nitrite N (ppm)	0.009	0.018	0.026	0.018	0.018
Nitrate N (ppm)	0.10	0.10	0.06	0.06	0.08
Organic N (ppm)	0.5	0.6	0.6	0.9	0.7
BOD, 5 day (ppm)	1.5	1.7	1.7	1.9	1.7
BOD, 30 day (ppm)	3.5	3.4	3.9	4.5	3.8
Color (ppm)	5	10	20	15	13

Table A-62

Lake Survey-Grand River-Depth 5 Ft.
Station G-24.8

Field Data	Oct. 2	Oct. 4	Oct. 8	Oct. 10	Average
Time (AM)	8:40	-	-	-	-
Temp. (°F)	70.7	71.6	69.7	69.0	70.3
pH	7.6	7.5	7.7	8.1	7.7
DO (ppm)	6.9	6.8	6.5	7.0	6.8
Laboratory Data					
pH	8.3	8.3	8.1	8.3	8.3
Phth. (ppm)	3	3	1	4	3
Alkalinity					
M.O. (ppm)	103	103	99	106	103
Chloride (ppm)	13.4	15	15	-	14
Ammonia N (ppm)	0.23	0.12	0.34	0.17	0.22
Nitrite N (ppm)	0.021	0.003	0.006	0.011	0.010
Nitrate N (ppm)	0.11	0.09	0.07	0.08	0.09
Organic N (ppm)	0.7	0.6	0.8	1.0	0.8
BOD, 5 day (ppm)	1.8	1.6	1.4	1.6	1.6
BOD, 30 day (ppm)	2.6	4.2	2.5	3.7	3.3
Color (ppm)	5	10	5	5	6
Coliform, Surf., $\left(\frac{MPN}{100\ ml}\right)$	1600	≥2400	180	140	≥560(e)

(e) log mean

Table A-63

Lake Survey-Grand River-Depth 23.5 Ft.
Station G-24.8

Field Data	Oct. 2	Oct. 4	Oct. 8	Oct. 10	Average
Time (AM)	-	-	-	-	-
Temp (°F)	70.7	71.5	69.6	68.7	70.1
pH	7.6	7.6	7.6	8.1	7.7
DO (ppm)	7.0	6.2	6.4	7.0	6.7
Laboratory Data					
pH	8.2	8.3	8.2	8.3	8.2
Phth. (ppm)	3	4	2	3	3
Alkalinity					
M.O. (ppm)	103	105	100	106	104
Chloride (ppm)	14	16	16	-	15
Ammonia N (ppm)	0.25	0.18	0.25	0.22	0.23
Nitrite N (ppm)	0.02	0.015	0.020	0.011	0.017
Nitrate N (ppm)	0.08	0.07	0.08	0.09	0.08
Organic N (ppm)	0.6	0.1	0.8	0.9	0.6
BOD, 5 day (ppm)	2.3	1.2	1.6	1.4	1.6
BOD, 30 day (ppm)	$\geq$7.9	3.7	3.2	3.9	$\geq$4.7
Color	5	5	5	5	5

Table A-64

Lake Survey-Grand River-Depth 42 Ft.
Station G-24.8

Field Data	Oct. 2	Oct. 4	Oct. 8	Oct. 10	Average
Time (AM)	-	-	-	-	-
Temp (°F)	70.1	71.0	69.6	68.6	69.8
pH	7.6	7.5	7.6	8.1	7.7
DO (ppm)	6.5	4.7	4.7	7.0	5.7
Laboratory Data					
pH	8.1	8.0	8.2	8.3	8.2
Phth. (ppm)	2	0	2	3	2
Alkalinity					
M.O. (ppm)	103	105	100	104	103
Chloride (ppm)	15.3	16	15.5	-	16
Ammonia N (ppm)	0.47	0.28	0.37	0.31	0.36
Nitrite N (ppm)	0.020	0.015	0.013	0.009	0.014
Nitrate N (ppm)	0.09	0.11	0.08	0.11	0.10
Organic N (ppm)	0.8	0.6	0.9	1.0	0.8
BOD, 5 day (ppm)	2.2	2.0	1.9	1.5	1.9
BOD, 30 day (ppm)	≧8.0	4.2	3.9	4.1	≧5.1
Color	15	5	5	10	9

Table A-65

Lake Survey-Grand River-Depth 5 Ft.
Station G-19.2

Field Data	Oct. 2	Oct. 4	Oct. 8	Oct. 10	Average
Time (AM)	9:00	-	-	9:30	-
Temp. (°F)	71.5	71.5	70.2	69.0	70.6
pH	7.6	7.5	7.6	7.7	7.6
DO (ppm)	6.8	7.3	6.4	6.35	6.7
Laboratory Data					
pH	8.2	8.4	8.1	8.1	8.2
Phth. (ppm)	3	4	1	1	2
Alkalinity					
M.O. (ppm)	104	101	101	103	102
Chloride (ppm)	12	14	13	-	13
Ammonia N (ppm)	0.15	0.13	0.37	0.28	0.23
Nitrite N (ppm)	0.003	0.003	0	0	0.002
Nitrate N (ppm)	0.08	0.09	0.07	0.07	0.08
Organic N (ppm)	0.7	0.7	0.6	0.8	0.7
BOD, 5 day (ppm)	1.8	2.5	1.0	0.8	1.5
BOD, 30 day (ppm)	3.9	5.6	5.3	2.7	4.4
Color (ppm)	5	5	5	10	6
Coliform, Surf., ($\frac{MPN}{100\ ml}$)	33	79	49	23	41(e)

(e) log mean

Table A-66

Lake Survey-Grand River-Depth 26.5 Ft.
Station G-19.2

Field Data	Oct. 2	Oct. 4	Oct. 8	Oct. 10	Average
Time (AM)	-	-	-	-	-
Temp. (°F)	70.7	70.7	70.0	69.0	70.1
pH	7.6	7.4	7.5	7.7	7.5
DO (ppm)	5.9	5.4	6.85	6.45	6.2
Laboratory Data					
pH	8.1	8.1	8.1	8.1	8.1
Phth. (ppm)	2	1	2	2	2
Alkalinity					
M.O. (ppm)	105	101	100	100	102
Chloride (ppm)	13	14.5	14	-	14
Ammonia N (ppm)	0.21	0.20	0.46	0.30	0.29
Nitrite N (ppm)	0.013	0.009	0.003	0	0.006
Nitrate N (ppm)	0.10	0.13	0.08	0.10	0.10
Organic N (ppm)	0.5	0.5	0.8	0.9	0.7
BOD, 5 day (ppm)	1.8	1.2	1.1	1.1	1.3
BOD, 30 day (ppm)	3.5	3.3	4.7	3.0	3.6
Color (ppm)	5	5	5	15	8

Table A-67

Lake Survey-Grand River-Depth 48 Ft.
Station G-19.2

Field Data	Oct. 2	Oct. 4	Oct. 8	Oct. 10	Average
Time (AM)	-	-	-	-	-
Temp. (°F)	70.5	70.3	69.8	69.0	69.9
pH	7.6	7.2	7.5	8.1	7.6
DO (ppm)	4.9	2.8	6.3	6.50	5.1
Laboratory Data					
pH	8.1	8.1	8.2	8.2	8.2
Phth. (ppm)	2	1	2	2	2
Alkalinity					
M.O. (ppm)	105	107	100	103	104
Chloride (ppm)	12.4	15.8	15	-	14
Ammonia N (ppm)	0.38	0.31	0.54	0.31	0.39
Nitrite N (ppm)	0.018	0.030	0.004	0	0.013
Nitrate N (ppm)	0.09	0.13	0.10	0.08	0.10
Organic N (ppm)	0.5	0.7	0.9	0.9	0.8
BOD, 5 day (ppm)	1.8	1.9	1.9	1.1	1.7
BOD, 30 day (ppm)	3.8	4.2	5.7	3.1	4.2
Color (ppm)	10	5	15	15	11

Table A-68

Lake Survey - Grand River - Depth 5 feet
Station G-13.7

Field Data	Oct. 2	Oct. 4	Oct. 8	Oct. 10	Average
Time (AM)	12:15 PM	-	-	8:15	-
Temp. (°F)	72.0	73.5	70.5	69.7	71.4
pH	8.2	7.5	7.6	7.7	7.7
DO (ppm)	8.1	8.1	6.55	6.45	7.3
Laboratory Data					
pH	8.4	8.5	8.2	8.1	8.3
Phth. (ppm)	5	6	2	1	4
Alkalinity					
M O. (ppm)	102	105	100	101	102
Chloride (ppm)	13	13	13	-	13
Ammonia N (ppm)	0.05	0.15	0.31	0.26	0.19
Nitrite N (ppm)	0	0.009	0.003	0	0.003
Nitrate N (ppm)	0.08	0.09	0.08	0.06	0.08
Organic N (ppm)	0.5	0.6	0.7	0.9	0.7
BOD, 5 day (ppm)	1.8	1.5	1.2	1.1	1.4
BOD, 30 day (ppm)	5.7	4.1	3.4	2.8	4.0
Color (ppm)	5	5	5	5	5
Coliform, Surf., (MPN/100Ml)	17	14	33	79	28(a)

(a) Log mean

Table A-69

Lake Survey - Grand River - Depth 30 feet
Station G-13.7

Field Data	Oct. 2	Oct. 4	Oct. 8	Oct. 10	Average
Time (AM)	-	-	-	-	-
Temp. (°F)	71.0	71.0	70.2	69.7	70.5
pH	7.6	7.7	7.5	7.7	7.6
DO (ppm)	5.9	5.9	6.4	6.3	6.1
Laboratory Data					
pH	8.2	8.2	8.2	8.1	8.2
Phth. (ppm)	2	2	2	1	2
Alkalinity					
M.O. (ppm)	105	103	98	103	102
Chloride (ppm)	11.6	12	12	-	12
Ammonia N (ppm)	0.25	0.20	0.10	0.24	0.20
Nitrite N (ppm)	0	0.004	0	0	0.001
Nitrate N (ppm)	0.09	0.10	0.05	0.07	0.08
Organic N (ppm)	0.6	0.6	0.6	0.8	0.7
BOD, 5 day (ppm)	1.8	1.1	1.2	1.3	1.4
BOD, 30 day (ppm)	4.1	2.9	3.7	2.9	3.4
Color (ppm)	5	5	5	5	5

Table A-70

Lake Survey-Grand River-Depth 55 Ft.
Station G-1[illegible].7

Field Data	Oct. 2	Oct. 4	Oct. 6	Oct. 10	Average
Time (AM)	-	-	-	-	-
Temp. (°F)	70.8	70.5	70.1	69.7	70.3
pH	-	7.4	7.4	8.0	7.6
DO (ppm)	5.1	3.5	6.2	5.6	5.1
Laboratory Data					
pH	8.0	8.0	8.1	8.2	8.1
Phth. (ppm)	0	0	2	1	1
Alkalinity					
M.O. (ppm)	105	107	100	103	104
Chloride (ppm)	13.3	12.2	12	-	13
Ammonia N (ppm)	0.23	0.38	0.15	0.24	0.25
Nitrite N (ppm)	0.004	0.013	0	0	0.004
Nitrate N (ppm)	0.10	0.10	0.07	0.06	0.08
Organic N (ppm)	0.5	0.6	1.0	0.9	0.8
BOD, 5 day (ppm)	1.9	1.8	1.6	0.9	1.8
BOD, 30 day (ppm)	4.4	4.3	4.2	5.0	4.5
Color (ppm)	10	5	5	5	6

Table A-71

Lake Survey-Grand River-Depth 5 Ft.
Station G-7.7

Field Data	Oct. 2	Oct. 4	Oct. 8	Oct. 10	Average
Time (AM)	11:45	-	-	7:30	-
Temp. (°F)	71.2	71.3	70.6	69.8	70.7
pH	7.7	8.2	7.6	7.7	7.8
DO (ppm)	6.5	9.0	6.97	6.5	7.2
Laboratory Data					
pH	8.3	-	8.2	8.1	8.2
Phth. (ppm)	3	-	2	2	2
Alkalinity					
M.O. (ppm)	103	-	99	102	101
Chloride (ppm)	13.5	12.8	12.5	-	13
Ammonia N (ppm)	0.03	0.09	0.10	0.07	0.07
Nitrite N (ppm)	0	0	0	0	0
Nitrate N (ppm)	0.18	0.08	0.03	0.07	0.09
Organic N (ppm)	0.4	0.8	0.6	0.9	0.7
BOD, 5 day (ppm)	1.8	-	1.4	1.0	1.4
BOD, 30 day (ppm)	5.5	-	3.5	3.3	4.1
Color (ppm)	5	5	5	5	5
Coliform, Surface (MPN/100ml)	49	14	17	13	20 (e)

(e) Logarithmic Mean

Table A-72

Lake Survey-Grand River-Depth 33.5 Ft.
Station G-7.7

Field Data	Oct. 2	Oct. 4	Oct. 8	Oct. 10	Average
Time (AM)	-	-	-	-	-
Temp. (°F)	70.3	70.0	70.4	69.8	70.1
pH	7.6	7.7	7.4	7.7	7.6
DO (ppm)	5.9	5.6	5.5	6.6	5.9
Laboratory Data					
pH	8.1	8.2	8.0	8.2	8.1
Phth. (ppm)	2	2	0	1	1
Alkalinity					
M.O. (ppm)	103	100	98	102	101
Chloride (ppm)	12.7	12.1	12.5	-	12
Ammonia N (ppm)	0.12	0.16	0.26	0.15	0.17
Nitrite N (ppm)	0	0	0	0.003	0.001
Nitrate N (ppm)	0.13	0.16	0.08	0.05	0.11
Organic N (ppm)	0.4	0.6	0.6	0.9	0.6
BOD, 5 day (ppm)	2.1	1.1	1.2	1.2	1.4
BOD, 30 day (ppm)	3.9	2.6	3.1	3.5	3.3
Color (ppm)	5	5	5	5	5

Table A-73

Lake Survey-Grand River-Depth 62 Ft.
Station G-7.7

Field Data	Oct. 2	Oct. 4	Oct. 6	Oct. 10	Average
Time (AM)	-	-	-	-	-
Temp. (°F)	69.9	69.0	70.2	69.5	69.6
pH	7.5	-	-	7.7	7.6
DO (ppm)	4.8	4.1	4.6	6.4	5.0
Laboratory Data					
pH	8.1	8.1	7.9	8.4	8.1
Phth. (ppm)	1	1	0	3	1
Alkalinity					
M.O. (ppm)	104	103	99	103	102
Chloride (ppm)	13.3	12	12	-	12
Ammonia N (ppm)	0.26	0.12	0.30	0.25	0.23
Nitrite N (ppm)	0.011	0	0.003	0	0.004
Nitrate N (ppm)	0.20	0.10	0.11	0.04	0.11
Organic N (ppm)	1.0	0.8	0.6	1.1	0.9
BOD, 5 day (ppm)	2.2	1.7	1.8	1.9	1.9
BOD, 30 day (ppm)	3.6	3.9	4.4	5.2	4.3
Color (ppm)	5	5	5	5	5

Table A-74

Spavinaw Creek -- State Highway 20
Station SP

	Sept. 26
Field Data	
Time (AM)	7:25
Temp. (°C)	20
pH	7.5
DO (ppm)	6.05
Laboratory Data	
pH	7.7
Phth. (ppm)	0
Alkalinity	
M.O. (ppm)	101
Chloride (ppm)	26
Ammonia N (ppm)	0.23
Nitrite N (ppm)	0
Nitrate N (ppm)	0.02
Organic N (ppm)	0.7
BOD, 5 day (ppm)	0.76
Color (ppm)	15

Table A-75

Chouteau Creek - State Highway 33
Station CH

Field Data	Sept. 20	Sept. 26	Average
Time (AM)	-	8:45	-
Temp. (°C)	-	20	-
pH	-	7.2	-
DO (ppm)	-	4.3	-
Laboratory Data			
pH	7.5	7.9	7.7
Phth. (ppm)	0	0	0
Alkalinity			
M.O. (ppm)	124	112	118
Chloride (ppm)	123	122	122
Ammonia N (ppm)	0.12	0.21	0.17
Nitrite N (ppm)	0	0	0
Nitrate N (ppm)	0.05	0.02	0.03
Organic N (ppm)	1.0	1.0	1.0
BOD, 5 day (ppm)	1.0	0.92	0.96
Color (ppm)	15	15	15

Table A-76

Big Cabin Creek - State Highway 28
Station BC

	Sept. 20	Sept. 26	Average
Field Data			
Time (AM)	-	6:45	-
Temp. (°C)	-	19	-
pH	-	7.5	-
DO (ppm)	-	5.8	-
Laboratory Data			
pH	7.6	8.0	7.8
Phth. (ppm)	0	0	0
Alkalinity			
M.O. (ppm)	120	106	113
Chloride (ppm)	32	26	29
Ammonia N (ppm)	0.10	0.38	0.24
Nitrite N (ppm)	0	0	0
Nitrate N (ppm)	0.05	0.02	0.03
Organic N (ppm)	1.1	1.1	1.1
BOD, 5 day (ppm)	2.5	1.1	1.8
Color (ppm)	15	10	12

APPENDIX B

INTRODUCTION

During the past several years several fish kills of major importance have occurred in Pryor Creek and Grand River. These kills have occurred at various times of the year and have been so extensive that fish have piled up along the shoreline of Grand River for 20 miles or more. The odor from decomposing fish has been so intense that persons normally visiting the reservoir for recreation purposes were not able to remain in the area. Numerous observations of fish kills by qualified persons have led them to conclude that the cause of fish kills in Grand River was due to pollution from Pryor Creek.

Pollution of Pryor Creek by a chemical plant and two paper mills located six to eight miles above the mouth of the creek causes discoloration of the water and produces strong odors of ammonia and hydrogen sulfide in the creek. A study of the effects of these wastes in Pryor Creek and in Grand River on living organisms was the primary purpose of the biological studies.

Sampling stations were established on Pryor Creek above and below the sources of pollution and also on Grand River above and below Pryor Creek.

Samples of water were obtained from Pryor Creek for fish toxicity studies.

The studies reported present information on algae and animal life present at various stations in the streams and information on the effect of polluted water on fish life obtained through field and laboratory studies.

The studies were conducted in August, September and October of 1956 following a dry summer period. Pryor Creek was not a flowing stream above the effluent discharged from the Pryor Sewage Treatment Plant. There were, however, sizeable pools of water in which fish and other aquatic life lived. At the time of the studies and for several weeks prior, the flow of Pryor Creek slowly entered Grand River where it was diluted.

Chemical analyses of the effluents, creek and reservoir, hydrologic data, engineering facts, and other information is contained in the main report.

ACKNOWLEDGMENTS

The biological studies were conducted cooperatively by the Public Health Service, Oklahoma State Health Department and the Oklahoma Game and Fish Department.

Mr. LeRoy Rachaels of the Oklahoma State Health Department conducted fish toxicity studies and assisted with plankton and bottom collections. Mr. Ronald Elkin and Mr. Al Houser of the Oklahoma Game and Fish Department provided boat transportation, assisted with the plankton and bottom sampling, conducted fish population studies in Pryor Creek and provided supplies of fish for the toxicity studies. Mr. John King, Oklahoma Game and Fish Department assigned personnel and rendered other helpful assistance. Mr. Sam Jackson, biologist for the City of Tulsa assisted with the fish population studies.

SUMMARY AND CONCLUSIONS

1. Biological studies consisting of the collection and enumeration of fish, plankton, and bottom organisms were conducted in Pryor Creek and Grand River. In addition, toxicity studies using fish were made on Pryor Creek water which was collected from various places in the creek.

2. Fish populations in Pryor Creek above the sources of industrial wastes consisted of a variety of species of fish. From seven to twelve species were collected, representing game and rough fishes. Pryor Creek contained no fish in the area polluted with industrial wastes. From one to one and a half miles above the mouth of Pryor Creek many fish consisting almost entirely of shad inhabited the upper portion of the water. The water in which fish were living flowed into the creek from the reservoir.

3. A variety of plankton was found in Pryor Creek and Grand River. No general conclusion can be drawn from a limited sampling program concerning any adverse effects of Pryor Creek water on the plankton population of Grand River. Grand River both above and below Pryor Creek had a variety of plankton which would be considered normal for the stream. A large increase in some of the species could present serious problems for a municipal water supply. Further studies would be needed to detect significant population trends. The variety of plankton found in Pryor Creek above pollution was destroyed in the polluted portion of the creek. Oscillatioria grew profusely in the polluted portion of the creek.

4. Pryor Creek above pollution supported a variety of bottom organisms including several forms intolerant of pollution. From the point of entry of industrial waste effluent on down to the mouth of the creek bottom fauna were unable to survive. Mosquitoes (culex) and a small fly species grew profusely in the polluted lower portion of the creek. The fly larvae were growing in the floating solids masses. In Grand River a variety of bottom fauna was found. Sampling in this stream was difficult due to the large rocks and rock bottom in many places and deep water. A variety of bottom organisms including sensitive mayflies was found at each of the four stations. The limited sampling program revealed no evidence of harmful effects of Pryor Creek water on bottom fauna in Grand River. A sampling program extending over a much longer period of time is indicated in order to detect possible harmful effects of pollution from Pryor Creek.

5. Fish toxicity studies indicated that Pryor Creek water from the mouth up to the area receiving industrial wastes was toxic to fish in concentrations ranging from 2% to 15%. All fish died in test solutions containing 1 ppm or more sulfide. Concentrations of 25 ppm ammonia nitrogen killed all test fish. Half this concentration was acutely toxic to a portion of the test fish.

Due to the volatile nature of the toxic components in test solutions the toxicity of the solutions decreased rapidly upon standing. In some cases fish were immobilized and then recovered as the toxic characteristics of the solution decreased.

Fish, consisting mostly of shad, lived in the top portion of the water from the mouth of Pryor Creek to about one to one and a half miles upstream. Toxicity tests showed that the water near the bottom of the creek in this area was toxic to fish.

6. At the time of the studies and for several weeks prior, dry weather prevailed. The flow of water from Pryor Creek to Grand River consisted entirely of Pryor sewage lagoon effluent, chemical plant effluent, paper mill effluent and cooling water. The dilution afforded by Grand River was obviously great. A sudden discharge of toxic Pryor Creek water into the river, greatly reducing the dilution ratio, would be expected to kill or adversely affect fish, certain bottom fauna and plankton. Re-population of the affected area by fish and plankton would be expected to occur in a very short time. Bottom fauna would require a longer period. The studies did not reveal continuous damaging effects to fish, plankton and bottom organisms in Grand River by pollution from Pryor Creek. The very toxic characteristics of Pryor Creek water from the mouth to about mile 8 posed a threat to Grand River which could easily result in an extensive fish kill such as has been observed frequently by persons in the area.

FISH POPULATION STUDIES

During the week of September 11-14, 1956, fish population studies were conducted at five locations on Pryor Creek for the purpose of determining the kinds, numbers, and sizes of fish present. Sampling stations were selected above, and below, sources of pollution in order to obtain data on fish populations that could be related to the existing sources of pollution.

Fish were collected by killing them with Pro-Noxfish, a liquid preparation containing rotenone and other active ingredients. The volume of water was estimated at each station and Pro-Noxfish applied in sufficient quantity to produce a kill. At least one part per million was applied to each estimated volume of water. Fish were collected as they came to the surface. The treated area was visited on the day following treatment to collect any additional fish that may have floated to the surface.

The following stations were selected for determining the fish populations present:

Station 1 - 14.0 miles above mouth. About 1 mile west of Highway 69 and one-half mile west of sewage treatment plant. This station is located upstream from the sewage treatment plant outfall. The stream was not flowing.

Station 2 - 10.0 miles above the mouth. This is about 0.4 mile above the Deere Co. outfall and 3.5 miles below the Pryor sewage treatment plant. The stream had a small flow.

Station 3 - 9.8 miles above the mouth. This is about 0.2 mile above the Deere Co. outfall and 3.7 miles below the Pryor sewage treatment plant. The water was yellow-green in color with ammonia odor present indicating Deere Co. effluent backed upstream to this station. The stream had a small flow.

Station 4 - 2.0 miles above mouth. This is below all sources of pollution. The water was black. Sludge was present on the bottom and suspended in the water and a strong sulfide odor apparent.

Station 5 - 1.0 mile above the mouth. The lake backs up into Pryor Creek and covers the black creek water. The color at the surface is quite similar to that in the lake. Black sludge is present on the bottom here and down to the mouth.

At Station 1, which is above the pollution, 320 fish were collected with more than 12 species represented. In addition, several species of minnows were included in the miscellaneous small fish group. Information on the total weight and lengths of individual fish for each listed species was obtained for the fish collected at this station.

At Station 2, which is below the Pryor sewage treatment plant and above the Deere Co. effluent, 258 fish were collected with more than 7 species represented. Desirable game fish types were well represented in the collection.

At Station 3, which was affected by the chemical plant effluent, and at Station 4, which was affected by effluents from the chemical and paper mills, no fish life was present.

At Station 5, which was one mile above the mouth of the creek and where the lake water was apparent on the surface, a large number (thousands) of young of the year shad were killed in the treated area. A few adult shad, two blue gills, and one carp were also found at this station. There is a slight possibility that additional fish were in this sampled area. The volume of water at this station greatly exceeded that of the other stations. The creek was approximately 40 feet wide. Pro-Noxfish was applied to approximately 75 feet of stream length. Average depth was about 8 feet. Some spread of the applied material resulted from wind and current. It appeared that the fish at this station were living in the upper zone of water which consisted of lake water that flowed over Pryor Creek water. On several occasions it was observed that shad surface activity in Pryor Creek varied in distance from the mouth of the creek. The distance that shad penetrated into Pryor Creek is undoubtedly related to the flow of water from the lake which afforded a suitable environment for these fish.

Data are presented in table form for Stations 1 and 2. From these tables (B-1 and B-2) it can be readily ascertained that Pryor Creek, above the sources of pollution and also below the Pryor sewage treatment plant, supports a variety of desirable game fish. At Stations 3 and 4 no fish life are present due to the presence of industrial wastes. At Station 5 the fish, which are predominately young shad, enter the creek from the lake and are able to live in the layer of lake water that lies over the polluted Pryor Creek water.

Table B-1

Fish Population in Pryor Creek - Station 1

Kind of Fish	Channel Cat	Carp	Warmouth Bass	River Carp Sucker	White Crappie
Number	18	13	19	15	14
Weight(lbs.)	5.32	10.5	1.06	0.5	1.25
Avg. Tot. Length (inches)	6.7	13.7	4.1	4.7	5.2
Range in Length	2.7-19.0	10.3-16.5	2.0-6.1	3.0-5.7	2.8-8.6

Kind of Fish	Gizzard Shad	Blue Gill	Green Sunfish	Red Ear Sunfish	Yellow Bullhead
Number	57	4	20	1	1
Weight (lbs.)	1.62	0.25	0.15	0.03	-
Avg. Tot. Length (inches)	5.6	5.2	3.1	4.8	3.4
Range in Length	5.0-6.1	4.6-5.5	1.6-4.0	-	-

Kind of Fish	Largemouth Bass	Short Nose Gar		Misc. Sunfish	Misc. Small Fish
Number	1	1		92	58
Weight (lbs.)	0.5	1.25		0.5	0.25
Avg. Tot. Length (inches)	10.9	10.2		-	-
Range in Length	-	-		-	-

Total Number of Fish - 320

Total Weight - 23.15 lbs.

Size of Area: 150 by 50 by 2 feet average depth

Volume - 0.34 acre feet

Location: 14.0 miles above mouth - stream not flowing

Table B-2

Fish Population in Pryor Creek - Station 2

(Approximately 8,800 cu. ft. or 0.2 acre foot - 10.0 miles above mouth)

Kind of Fish	Largemouth Bass	Green Sunfish	Orange Spotted Sunfish	Warmouth Bass	White Crappie
Number	3	43	27	2	3
Avg. Tot. Length (inches)	7.0	2.6	2.1	4.0	6.3
Range in Length	6.2-7.4	1.0-5.8	1.4-2.9	3.6-4.5	5.6-6.6

Kind of Fish	Channel Cat	Black Bullhead	Misc. Sunfish	Misc. Small Fish
Number	1	97	66	16
Avg. Tot. Length (inches)	3.9	2.3	-	-
Range in Length	-	1.6-5.0	-	-

Total Number of Fish - 258

Size of Area: 110 by 40 by 2 ft. - Average depth -
volume 0.20 acre ft.

Location. 10.0 miles above mouth - stream flowing

FISH TOXICITY STUDIES

Samples of water from several stations on Pryor Creek and the effluent from the Deere Co. waste pond were collected and tested for toxicity to fish. Red fin shiners (Notropis lutrensis) collected from the Verdigris River west of Wagoner, Oklahoma were used. These minnows ranged in length from one and a half to three inches. For a few of the initial tests the red ear sunfish (Lepomis microlopus) obtained from a State fish hatchery were used but because of their larger size it was difficult to maintain adequate oxygen in the test jars without constant aeration. It was observed that the red ear sunfish were more resistant than the red fin shiners.

The toxicity studies were conducted in a mobile trailer laboratory equipped with a refrigerator type air conditioner, thermostatically controlled for cooling. Electrical heating facilities were also available. Generally the temperatures were maintained between 74° and 78° Fahrenheit. Most of the tests were made in five-gallon wide mouth jars containing 15 liters of test solution. Twenty red fin shiners placed in this amount of solution did not appreciably lower oxygen concentrations. Aeration facilities were used whenever it appeared that oxygen concentrations were getting too low from any cause. A few tests, mostly of an exploratory nature, were conducted in one-gallon jars containing three liters of test solution. Not more than five red fin shiners were placed in the gallon jars.

Test solutions were prepared using Pryor city water for dilution purposes. The source of this water was from Grand River obtained a short distance above the mouth of Pryor Creek. The small amount of chlorine in this water was not sufficient to affect fish and it was well aerated before use to insure removal of trace quantities of chlorine. The appropriate amount of sample was added to each test jar. Fish were observed at intervals to determine when mortality occurred and tests were conducted for at least 48 hours or until 100% mortality occurred. No mortality was observed in the controls which were maintained for all tests. Except for the first day or two that fish were placed in the stock containers, there were very few fish that died among the stock supply.

Chemical analyses, including concentration of dissolved oxygen, alkalinity, nitrogen, sulfide and pH were determined for various samples. The pH values of the test solutions varied from 6.6 to 8.2 though for most test solutions values were near 7.0. Alkalinity values ranged from 85 to 153 and were generally in the range of 95 to 120. Oxygen values less than 2.0 ppm did appear in some cases, but whenever low oxygen was suspected aeration was begun to raise the concentration to 5.0 ppm or more. Fish were killed rapidly in some solutions and from the behavior of the fish, toxicity rather than deficient oxygen was obviously the primary cause of death.

The data obtained from the various tests were arranged in tables according to the stations from which water was collected. The concentration at which 50% mortality would occur was not determined in these tests for two reasons; (1) the apparent concentrations at which mortality occurred varied considerably because of the volatile nature of the toxic materials, (2) it was not deemed practical to run a sufficient number of tests to determine a concentration lethal to 50% of the fish because for most samples there was a relatively small difference in concentration which produced 100% or a low mortality rate.

TOXICITY TEST RESULTS

MOUTH OF PRYOR CREEK

Samples of water taken from near the bottom at the mouth of Pryor Creek were toxic to the test fish (Notropis lutrensis). Concentrations as low as 10% Pryor Creek water killed 20% of the test fish and a concentration of 15% caused 100% mortality. The samples collected from this station had variations in toxicity. The volatile nature of the toxic materials, methods of collecting and handling the waste, and techniques of testing were largely responsible for the variations in toxicity. Sulfide determinations for one of the samples collected gave values of 2.8, 4.0, and 4.2 parts per million sulfide for concentrations of 25%, 30%, and 35% respectively. 100% mortality occurred within 15 minutes for each of these samples.

In Table 1 it is readily apparent that there are variations in the toxicity of test solutions of the same concentrations. One of the reasons for this is that four different samples were used and the sulfide content probably varied considerably. There are, however, variations in the toxicity of equal concentrations of the same sample. For instance, a 20% solution killed the test fish in 10 minutes but killed only 35% when there was a 15 minute delay of time between the preparation of the test solution and the addition of fish. In several instances it was noted that the toxicity of the solution decreased rapidly with time. The method of preparing the solution was also important. Solutions prepared by carefully siphoning the sample into dilution water were more toxic than those prepared by pouring the sample into the dilution water. Vigorous mixing also affected the toxicity of the test solution. In all of the test solutions it was observed that fish usually died or reacted to the toxic materials within the first few minutes. In several of the tests fish that survived the 48 hour test period turned up or swam about with little control of their movements during the first few minutes of the test. At the end of these tests the fish that survived appeared normal in every respect.

MILE 1.7 AND MILE 3.0

Data obtained from test conducted on samples from these stations are contained in Table 2. A sample collected from Mile 1.7 was toxic to the test fish (Notropis lutrensis) in concentrations ranging from 2 to 5%. The percent mortality at these concentrations varied from 5 to 100 percent. No data were obtained on the sulfide concentration of these test solutions though at mile 3.0 a 5% concentration of sample contained 1.6 ppm sulfide. Three tests on a sample from mile 3.0 showed that red fin shiner mortality was 10%, 20%, and 100% in sample concentrations of 1%, 2% and 4% respectively.

MILE 4.9 BELOW SOURCES OF POLLUTION

Table 3 contains data obtained with tests on Mile 4.9 water. A sample collected from Mile 4.9 was toxic to the test fish (Notropis lutrensis) in concentrations of 2.5% to 10%. 100% mortality was observed in three test solutions with sample concentrations of 5%, 7.5%, and 10%. Sulfide determinations indicated that the following amounts were present in three test solutions: 0.4 ppm sulfide in a test solution containing 2.5% of sample, 1.0 ppm sulfide in a test solution containing 5% of sample, and 2.0 ppm sulfide in a test solution containing 7.5% of sample.

MILE 6.1 BELOW THE BESTWALL CO. OUTFALL AND ABOVE NATIONAL GYPSUM CO. OUTFALL

Table 4 contains data for tests on water from Mile 6.1. Two samples collected from this location were toxic to fish (Notropis lutrensis) in concentrations ranging from 3 to 7.5%. 10% mortality occurred in a test solution containing 3% of sample which contained 0.6 ppm sulfide. One hundred percent mortality occurred in test solutions containing 5% and 7.5% of sample. The sulfide concentration of both the latter test solutions was 1.0 ppm at the time of the test.

MILE 8.6 BELOW THE DEERE CO. OUTFALL AND ABOVE THE BESTWALL CO. OUTFALL

Table 5 contains data for tests on water from Mile 8.6. Four samples were collected from this location. Variation in toxicity was noted which was probably due largely to the diluting effects of rainfall. Samples collected on October 3 and October 15 were toxic to fish in concentrations ranging from 2 to 5 percent. Mortality ranged from 30 to 100 percent. In the samples collected on October 20 and 24, mortality was not observed in test solutions containing two to five percent of sample. Nitrogen analyses showed that the sample collected on October 15 which caused toxicity contained 722 ppm nitrogen as ammonia while the sample collected on October 24 which was not toxic in the 2 to 5 percent concentrations contained 230 ppm nitrogen as ammonia or less than one-third as much as the October 15 sample. It was noted that the toxic test solutions had a pH of 8.2 and 8.3 while the non-toxic test solutions had pH values ranging from 7.4 to 7.8.

DEERE EFFLUENT

Data for Toxicity tests on water from this station are contained in Table 6. A sample of effluent from the Deere Co. lagoon was tested for toxicity to red fin shiners. A 2% test solution contained 50 ppm nitrogen as ammonia. Test solutions containing 0.5% sample exhibited a low degree of toxicity while solutions containing 1% or more were toxic to nearly all test fish during a 48 hour test period.

CONCLUSIONS

1. Samples of water collected from Pryor Creek were toxic to the red fin shiner minnow (Notropis lutrensis) in concentrations varying from 2% to 15%. These samples were collected from Mile 8.6 to the mouth. The Deere Co. effluent was toxic to nearly 100% of the test fish at a concentration of one percent.

2. Sulfide concentrations were determined for some of the test solutions. One hundred percent mortality occurred when sulfide was present in a concentration of 1 ppm or more. Other materials associated with anaerobic decomposition in the stream were not determined.

3. Nitrogen concentrations as ammonia were determined for samples of Deere effluent and stream samples at Mile 8.6. Concentrations of 12 to 15 ppm nitrogen were toxic to less than 50% of the fish. Concentrations of 25 ppm or more were toxic to all fish exposed.

4. Test solutions containing 1 ppm or more of sulfide killed the test fish quickly. Some of the test solutions which were toxic to fish lost their toxicity upon standing a short time indicating the volatile nature of the toxic substances.

5. Fish were observed at the surface in Pryor Creek over a mile upstream from the mouth. The toxicity tests indicated that the water near the bottom of the creek was toxic to fish life. Movement of this water plus the more toxic water upstream into Grand River without adequate mixing would cause a major fish kill.

Table B-3

Toxicity of Pryor Creek Water (Mile 0.0 bottom) to Red Fin Shiners (Notropis lutrensis)

	% of Sample in Test Solution	Number of Test Fish	% Mortality	Duration of Test (Hours)	Chemical pH	Chemical Sulfides ppm	Date Sample Collected
1	5	20	0	48	-	-	10-5-56
2	10	10	0	48	-	-	10-5-56
3	10	20	20	48	-	-	10-24-56
4	15	20	100	1 hr.45 min.	-	-	10-24-56
5	20	10	0	48	-	-	10-5-56
6	20	20	0	48	7.0	-	10-18-56
7	20 a	10	100	10 min.	-	-	10-24-56
8	20 b	20	35	48	-	-	10-24-56
9	25	20	100	15 min.	7.0	2.8	10-20-56
10	25	20	100	30 min.	-	-	10-24-56
11	30	20	100	15 min.	7.4	4.0	10-20-56
12	30	20	50	48	-	-	10-20-56
13	30	20	100	15 min.	-	-	10-24-56
14	35	20	100	15 min.	6.6	4.2	10-20-56
15	40	20	90	48	7.0	-	10-18-56

a - fish added to solution 15 minutes earlier than in b

Table B-4

Toxicity of Pryor Creek Water
(Mile 1.7 and 3.0) to Red Fin Shiners (Notropis lutrensis)

% of Sample in Test Solution	Number of Test Fish	% Mortality	Duration of Test (Hours)	Chemical		Date Sample Collected
				pH	Sulfides ppm	
Mile 1.7						
2	20	5	48	-		10-3-56
2	10	0	48	-		10-3-56
3	10	50	48	-		10-3-56
5	10	30	48	-		10-3-56
5	20	100	1 3/4	-		10-3-56
Mile 3.0						
1	20	10	48	7.0		10-18-56
2	20	20	48	7.0		10-18-56
4	20	100	1 3/4	7.0		10-18-56

Table B-5

Toxicity of Pryor Creek Water (Mile 4.9) to Red Fin Shiners (Notropis lutrensis)

% of Sample in Test Solution	Number of Test Fish	% Mortality	Duration of Test (Hours)	Chemical pH	Chemical Sulfides ppm	Date Sample Collected
2	10	0			-	10-10-56
2.5	10	20	48		0.4	10-10-56
5	10	100	3.5		1.0	10-10-56
5	10	10	48		-	10-10-56
7.5	10	100	0.3		2.0	10-10-56
10	9	100	0.75		-	10-10-56

Table B-6

Toxicity of Pryor Creek Water (Mile 6.1) to Red Fin Shiners (Notropis lutrensis)

% of Sample in Test Solution	Number of Test Fish	% Mortality	Duration of Test (Hours)	Chemical			Date Sample Collected
				pH	Alk.	Sulfide	
2	20	0	48	6.9	80	0.5	10-20-56
2.5	10	0	48	-	-	-	10-15-56
3	20	10	48	6.9	85	0.6	10-20-56
5	19	100	16.5	7.1	92	1.0	10-20-56
5	10	90	48	7.4	85	-	10-15-56
5	10	0	48	-	-	-	10-3-56
7.5	10	100	1.0	7.2	98	1.0	10-15-56
10	10	100	1.0	7.4	-	2.2	10-15-56
10	9	100	0.3	-	-	-	10-3-56

Table B-7

Toxicity of Pryor Creek Water (Mile 8.6) to Red Fin Shiners (Notropis lutrensis)

% of Sample In Test Solution	Number of Test Fish	% Mortality	Duration of Test (Hours)	Chemical			Date Sample Collected
				pH	Alk.	N as NH^3	
2	10	30	48	-	-	-	10-3-56
2	10	40	48	8.3	114	14.4	10-15-56
2	20	10	48	7.4	85	-	10-20-56
2	20	0	48	7.5	89	-	10-24-56
3	10	100	16	8.2	130	-	10-15-56
3	20	0	48	7.4	92	-	10-20-56
3	20	0	48	7.5	98	-	10-24-56
4	10	70	48	-	-	-	10-3-56
5	10	100	2.25	8.3	162	-	10-15-56
5	20	0	48	7.6	105	-	10-20-56
5	20	0	48	7.8	116	-	10-24-56

Table B-8

Toxicity of Deere Effluent to Red Fin Shiners (Notropis lutrensis)

% of Sample in Test Solution	Number of Test Fish	% Mortality	Duration of Test (Hours)	pH	Chemical Alk.	N as NH^3	Date Sample Collected
1	9	100	16.33	8.18	118	25	10-15-56
2	10	100	2.75	8.2	153	50	10-15-56
0.5	10	20	48	-	-	12.5	10-15-56
0.5	20	0	48	8.0	-	-	10-15-56
1	20	80	48	8.1	57.5	-	10-15-56
1.5	20	100	16.17	8.1	-	-	10-15-56

BOTTOM ORGANISMS

A study of the bottom organisms existing in Pryor Creek and Grand River was undertaken to provide data on the kinds of organisms which existed in the various environmental conditions of the creek and reservoir. This information is tabulated in Tables B-9 and B-10.

The various stations provided the following variety of environmental conditions:

(1) Pryor Creek consisted of separated pools of relatively unpolluted water at the uppermost station.

(2) Treated municipal sewage from a waste stabilization pond discharged to the creek above the next sampling station and created a small flow in the creek.

(3) The Deere plant effluent containing urea and ammonia discharged to the creek a short distance above mile 8.6 followed by discharge of paper mill effluents a short distance downstream.

(4) Pryor Creek consists of a series of pools and shallow riffles. The bottom varies from solid rock to gravel and in the lower portion where the creek becomes deeper (about 12 feet at the mouth) the bottom is covered with silt and sludge deposits. The level of the reservoir determines the water depth in Pryor Creek for two to three miles above the mouth of the creek and the flow of water in or out of the lower portion of the creek is dependent upon the reservoir level.

The reservoir level extends to the low water dam (Mile 43.5) which was the uppermost sampling station in Grand River. The bottom was rocky at this place with coarse gravel and stones near the shoreline. Downstream, various kinds of bottom types were found including rock, sand and silt deposits.

The collection of two sets of samples from each station is not adequate to provide information on the full range of organisms inhabiting each area. Especially in Grand River there is considerable difficulty in obtaining a representative sample. The presence of large rocks, deep water along the shore and sediment deposits provide such a variety of habitat that extensive sampling is needed to obtain information representative of the station. From the list of organisms obtained by sampling and general observations, a normal bottom fauna appeared to exist in Grand River both above and below Pryor Creek. Any effects on bottom organisms which might have resulted from the discharge of toxic waters from Pryor Creek could not be detected at the time of sampling.

The effect of pollution on bottom organisms in Pryor Creek was striking. Above pollution 112 organisms representing at least 14 species were collected. Downstream below the point where effluent from the Pryor sewage treatment plant discharged to the stream, and above industrial waste effluents, 43 organisms representing at least six species were collected. Though there was a smaller number of species found at this lower station, sensitive mayflies and snail species were represented indicating that water quality for bottom organisms was satisfactory. Bottom organisms could not be found below the points of discharge of chemical and paper mill wastes. At the mouth of Pryor Creek three organisms tolerant to pollution were found beyond the area of decomposing sludge deposits. Sludge deposits in the lower reach of Pryor Creek had the appearance of black crankcase oil. Some odor of hydrogen sulfide was noticed. No organisms were found in this material. The critical zone in which there was a complete absence of bottom organisms from the area in Pryor Creek where industrial wastes were discharged to the mouth of the creek. The dilution ratio of Grand River water to Pryor Creek water was obviously great at the time of the studies and probably occurred for several weeks prior to the studies.

PLANKTON STUDIES

The investigations of Pryor Creek and Grand River included collection of plankton organisms in August, September, and October.

The objectives of these studies were: (1) to determine the kinds and relative abundance of plankton at various sampling stations; and (2) note some of the conditions which stimulated or depressed plankton populations.

Two series of samples were concentrated with a plankton net, and a third group was concentrated with a centrifuge. Fresh unconcentrated samples were examined preliminary to the taking of samples from a series of stations for the purposes of estimating population density and viewing live specimens.

Since only limited sampling of plankton was done, it was felt that actual counts of plankton would not be particularly advantageous. For this reason, the plankton in the various samples have been reported in the following population groups: F - few; S - several; A - abundant. If a single plankter was found in ten or more fields examined, it was reported as few. If two to nine plankters were found in ten fields, several were reported; and if ten or more plankters were observed, they were reported as abundant. Net plankton were concentrated about 1,000 times and the centrifuged samples, about 50 times.

Table B-9

BOTTOM ORGANISMS

ORGANISMS	NUMBER OF ORGANISMS COLLECTED										
	PRYOR CREEK						GRAND RIVER				CHOUTEAU CREEK
	14.0	10.8	8.6	5.6	1	0	43.5	40	39	24.8	0
Mayflies-Baetidae	9	26					7				
Ephemeridae (hexagenia)	1						1	39		37	22
Heptagenidae							45		44	1	
Dragonflies											
Libellulidae	1								1		
Damselflies											
Coenogrionidae	4	4					6		12		
Flies (true)											
Tendipedidae	11	1				2	4	5		4	5
Chaoborus						1				1	2
Beetles											
Elmidae							28				
Helodidae									7	1	
Dytiscidae	2								4		
Hydraenidae	1										
Bugs (true)											
Corixidae	5										
Alderfly											
Sialis								1			
Molluscs											
Clams											
Unionidae	4										
Sphaeridae							4			1	1
Snails								4			
Ferrisa	45	2									
Physa	1	1					10				
Helisoma		9									
Worms											
Oligiochaetes	20						7	3		10	2
Leech											
Hirudinea	5										
Crustacea											
Hyalella	3										
Total Number	112	43	0	0	0	3	112	52	68	55	32
Total Number of kinds	14	6	0	0	0	2	9	5	5	7	5

Table B-10

BOTTOM ORGANISMS

Common Name	Classification	Number Collected Aug. 29-30	 Oct. 2-5
PRYOR CREEK - MILE 14 WEST OF SEWAGE TREATMENT PLANT			
Leech	Hirudinea	3	2
Snail	Gastropoda - Ferrisia	27	18
Snail	Gastropoda - Physa	1	
Clam	Pelecypoda - Unionidae - Ligumia	1	1
Clam	Pelecypoda - Unionidae - Lasmigona	1	1
Bug (Boatman)	Corixidae	5	
Beetle	Coleoptera - Hydraenidae	1	
Beetle (diving)	Coleoptera - Dytiscidae	2	
Scud	Crustacea - Hyalella	3	
Mayfly	Ephemeroptera - Baetidae	9	
Mayfly	Ephemeroptera - Hexagenia		1
Damselfly	Odonata - Coenogrionidae	3	1
Dragonfly	Odonata - Libellulidae		1
Midge	Diptera - Tendipedidae	2	9
Worm	Annelida - Tubificidae	2	18
	Total	60	52
PRYOR CREEK - MILE 10.8 ABOVE DEERE PLANT			
Snail	Gastropoda - Helisoma	6	3
Snail	Gastropoda - Physa		1
Snail	Gastropoda - Ferrisia	2	
Mayfly	Ephemeroptera - Baetidae	20	0
Mayfly	Ephemeroptera - Heptageniidae		6
Damselfly	Odonata - Coenogrionidae	2	2
Midge	Diptera - Tendipedidae		1
	Total	30	13
PRYOR CREEK - MILE 8.6		None	None
PRYOR CREEK - MILE 5.6		None	None

Table B-10 (contd)

BOTTOM ORGANISMS

Common Name	Classification	Number Collected Aug. 29-30	Number Collected Oct. 2-5
GRAND RIVER - MILE 40 ½ MILE ABOVE PRYOR CREEK			
Mayfly	Ephemeroptera - Hexagenia	29	10
Alderfly	Megaloptera - Sialis	1	
Snail	Gastropoda	4	
Worm	Annelida - Oligiochaete	2	1
Midge	Diptera - Tendipedidae	1	4
	Total	37	15
GRAND RIVER - MILE 39 AT HIGHWAY 33 EAST SIDE			No Sample
Mayfly	Ephemeroptera - Heptageniidae	25	
Damselfly	Zygoptera	11	
Dragonfly	Anisoptera	1	
Beetle (diving)	Coleoptera - Dytiscidae	4	
Beetle	Coleoptera - Helodidae	1	
	Total	42	
GRAND RIVER - MILE 39 AT HIGHWAY 33 - WEST SIDE			No Sample
Mayfly	Ephemeroptera - Heptageniidae	19	
Damselfly	Odonata - Coenogrionidae	1	
Beetle	Coleoptera - Helodidae	6	
	Total	26	
GRAND RIVER - MILE 24.8 AT WAGONER WATER INTAKE			
Mayfly	Ephemeroptera - Hexagenia	12	25
Mayfly	Ephemeroptera - Heptageniidae	1	
Clam	Pelycypoda - Sphaeridae		1
Worm	Annelida - Oligiochaete	3	7
Midge	Diptera - Tendipedidae	1	3
Midge	Diptera - Chaoborus	1	
Beetle	Coleoptera - Helodidae	1	
	Total	19	36

Table B-10 (contd)

BOTTOM ORGANISMS

Common Name	Classification	Number Collected Aug. 29-30	Oct. 2-5
PRYOR CREEK - NEAR MOUTH OF CREEK		None	
Midge	Diptera - Chaoborus		1
Midge	Diptera - Tendipedidae		2
	Total		3
CHOUTEAU CREEK - NEAR MOUTH OF CREEK			
Worm	Annelida - Tubificidae	2	
Midge	Diptera - Tendipedidae	5	
Midge	Diptera - Chaoborus		2
Mayfly	Ephemeroptera - Hexagenia		22
Clam	Pelecypoda - Sphaeridae		1
	Total	7	25
GRAND RIVER - MILE 43.5 - BELOW LOW WATER DA			
Mayfly	Ephemeroptera - Heptageniidae	41	4
Damselfly	Zygoptera	6	
Midge	Diptera - Tendipedidae	4	
Snail	Gastropoda - Physa	7	3
Clam	Pelecypoda - Spheridae	1	3
Worm	Annelida - Oligiochaete	1	6
Mayfly	Ephemeroptera - Hexagenia		1
Mayfly	Ephemeroptera - Baetidae		7
Beetle	Coleoptera - Elmidae		28
	Total	60	52

Upon examination of the tabulated data, it can be seen that the plankton populations consisted of a variety of organisms. Some organisms, such as pediastrum, the diatoms, and oscillatoria, appeared fairly consistently in most samples. Others, such as ankistrodesmus, scenedesmus, microspora, the rotifers, and crustacea, appeared frequently but not in each series of samples.

Above the reach of Pryor Creek into which industrial wastes discharged, a variety of plankton were present. The dark-colored water resulting from paper mill wastes supported little plankton except oscillatoria. This alga grew rather profusely on floating sludge masses and to a lesser extent in the upper portion of the stream. Other life in the stream from Mile 2 to 3 consisted of many culex mosquito larvae and a large number of small flies. From the mouth of the creek to approximately 1.5 miles upstream, a variety of algae were present. They were carried upstream by the flow of water from Grand River, and the variable distances they were carried at different times could easily be detected by the appearance of the water.

The stream immediately below the point of chemical plant waste discharge contained variable kinds of plankton. Only three kinds were found in the area immediately below the discharged effluent during October, but nine kinds were found in September. The reduction of effluent just prior to the September collection may have had a significant effect on the plankton population. Water flowing from the upstream station (Mile 10.0) contained a wide variety of plankton which would continuously seed the area receiving the chemical waste. The ability of the plankton to survive or reproduce in this area or downstream depends upon the environmental conditions existing in those areas. The growth of oscillatoria and the presence and apparent survival of algae introduced from the reservoir up into the mouth of the creek for a distance of approximately one and one-half miles is a condition of interest.

It is worthwhile to consider the value of a retention pond in stabilizing wastes through the oxidation and reduction processes that would be affected to a considerable degree by growing and reproducing algae. Experimental studies to determine the effects of mixtures of wastes on algal populations and rate of recovery could prove very useful in determining the rate of stabilization in an open pond receiving these wastes. The creek is heavily shaded by tall trees growing along the banks. This is not conducive to algal growth. An impoundment exposed to sunlight and wind should afford a more rapid rate of stabilization than presently occurs in the creek channel.

The plankton populations occurring in Grand River consisted of a fairly large variety. The significance attached to the plankton found there relates to the fact that a variety of kinds exist which are normally expected to be found in ordinary surface water. A regular sampling program over an extended period of time would be needed to indicate significant increases of populations which would have influence on water quality for domestic use.

The plankton collected at the mouth of Chouteau Creek consisted of several kinds existing in the reservoir and at the mouth of Pryor Creek. The water in these three locations was probably fairly uniform in chemical quality near the surface.

The sewage lagoon which discharges effluent to a tributary of Pryor Creek has a variable population of algae which is of interest. During a visit to this lagoon in March of 1956, it was observed that the algae consisted entirely of scenedesmus. In September 1956, the most abundant alga was microcystis, though chlorococcum, oscillatoria, arthrospira, and euglena were also present. In October the algal population consisted of microcystis, with no other kinds being observed.

Table B-11

PLANKTON

Net Collection
September 11-13, 1956

	PRYOR CREEK							GRAND RIVER					
	14.	10.	8.6	3	2	1	0	43.5	40	39	24.8	Mouth of Chouteau	Sewage Lagoon
PHYTO PLANKTON													
Chlorophyta (green)													
Pediastrum	No Sample	F	A		A	A	A	No Sample	A	A	No Sample	No Sample	
Coelastrum						S	F		F				
Ankistrodesmus									F				
Selenastrum													
Ulothrix			A						A	S			
Chlorella													
Volvox		A											
Chlamydomonas													
Zygnema			F										
Desmid													
Closterium		F											
Cosmarium													
Scenedesmus		S											
Pandorina		S											
Sphaerocystis													
Staurastrum		F											
Microspora													
Spirogyra			A										
Volvocales			A										
Chlorococcum													F
Cyanophyta (blue green)													
Oscillatoria		A	F	A	A	S	S			S			S
Mougeotia							F						
Spirulina		F											
Microcystis		F											A
Arthrospira													F
Gomphosphaeria													
Plectonema													
Merismopedia													
Bacillarieae (Diatoms)		A	A										
Fragilaria						S	S		F	F			
Cyclotella													
Pleurosigma													
Synedra													
Euglenophyta							F						S
Euglena													
Chrysophyta													
Uroglena							F		F	F			
Chlorobotrys						F				F			
Pyrrophyta													
Ceratium									F				
Peridinium													

Table B-11 (contd)

PLANKTON

Net Collection
September 11-13, 1956

Mile	PRYOR CREEK 14.	10.	8.6	3	2	1	0	GRAND RIVER 43.5	40	39	24.8	Mouth of Chouteau	Sewage Lagoon
ZOO PLANKTON													
Protozoa													
Ciliate			F	A	A	A	S		S				
Flagellate				A	A								
Rotifera					A								
Brachionus							A						
Polyartha						A			A	A			
Keratella			S			A			A	A			
Conochilus		A											
Pompholyx													
Crustacea								No Sample			No Sample	No Sample	
Nauplius	S	S					F			F			
Diaptomus		S											
Canthocamptus	S	S											
OTHER													
Insecta													
Chaobrus													
Nematoda													

Table B-12
PLANKTON

Net Collection
October 2-5, 1956

	PRYOR CREEK							GRAND RIVER					
Mile	14.	10.	8.6	3	1.5	1	0	43.5	40	39	24.8	Mouth of Chouteau	Sewage Lagoon
PHYTO PLANKTON				No Sample				No Sample					
Chlorophyta (green)													
Pediastrum	F					S	A		A	A	A	S	
Coelastrum													
Ankistrodesmus	A	F				F	F		F				
Selenastrum													
Ulothrix													
Chlorella													
Volvox		F											
Chlamydomonas													
Zygnema													
Desmid													
Closterium													
Cosmarium									F				
Scenedesmus	F	F					F						
Pandorina							F						
Sphaerocystis													
Staurastrum													
Microspora		F	F			A	S		A	A	A	A	
Spirogyra													
Volvocales													
Chlorococcum		F	S										
Cyanophyta (blue green)													
Oscillatoria					A	S	F			F			
Mougeotia												F	
Spirulina													
Microcystis											F		A
Arthrospira													
Gomphosphaeria	F												
Plectonema									F				
Merismopedia													
Bacillarieae (Diatoms)													
Fragilaria		F				F	F		S	S		S	
Cyclotella		F											
Pleurosigma		F											
Synedra					F								
Euglenophyta													
Euglena	F	F											
Chrysophyta													
Uroglena													
Chlorobotrys													
Pyrrophyta													
Ceratium											F		
Peridinium	F	A											

Table B-12 (contd)

PLANKTON

Net Collection
October 2-5, 1956

	PRYOR CREEK							GRAND RIVER					
Mile	14.	10.	8.6	3	1.5	1	0	43.5	40	39	24.8	Mouth of Chouteau	Sewage Lagoon
ZOO PLANKTON													
Protozoa			A										
Ciliate							F						
Flagellate													
Rotifera		S								F	F		
Brachionus													
Polyartha													
Keratella	S								F			F	
Conochilus													
Pompholyx		F		No Sample				No Sample					
Crustacea													
Nauplius	S	S					F				S	A	
Diaptomus													
Canthocamptus													
OTHER													
Insecta													
Chaobrus							F						
Nematoda		F											

Table [illegible]-13

PLANKTON

Centrifuged
August 30 - September 6, 1956

	PRYOR CREEK							GRAND RIVER					
Mile	14.	10.	8.6	3	1.5	1	0	43.5	40	39	24.8	Mouth of Chouteau	Sewage Lagoon
PHYTO PLANKTON													
Chlorophyta (green)													
Pediastrum								S	S				
Coelastrum								F				F	
Ankistrodesmus	No Samples												
Selenastrum								F					
Ulothrix									F				
Chlorella											A	A	
Volvox													No Sample
Chlamydomonas							S				F	A	
Zygnema								F					
Desmid								F				F	
Closterium													
Cosmarium													
Scenedesmus							F	S	F		F	F	
Pandorina													
Sphaerocystis							F				S		
Staurastrum													
Microspora													
Spirogyra													
Volvocales									A				
Chlorococcum													
Cyanophyta (blue green)													
Oscillatoria							F		F		S	F	
Mougeotia													
Spirulina											A		
Microcystis													
Arthrospira													
Gomphosphaeria								F	F				
Plectonema													
Merismopedia								S	A		S	F	
Bacillarieae (Diatoms)							S	A	A		A	S	
Fragilaria													
Cyclotella													
Pleurosigma													
Synedra													
Euglenophyta													
Euglena									F			F	
Chrysophyta													
Uroglena													
Chlorobotrys													
Pyrrophyta													
Ceratium													
Peridinium													

Table B-13 (contd)

PLANKTON

Centrifuged
August 30 - September 6, 1956

	PRYOR CREEK							GRAND RIVER					
Mile	14.	10.	8.6	3	1.5	1	0	43.5	40	39	24.8	Mouth of Chouteau	Sewage Lagoon
ZOO PLANKTON													
Protozoa													
Ciliate									F				
Flagellate													
Rotifera				No Samples									
Brachionus													
Polyartha													
Keratella													
Conochilus													
Pompholyx													
Crustacea													
Nauplius											F		
Diaptomus													
Canthocamptus													
OTHER													
Insecta													
Chaobrus													
Nematoda													

APPENDIX C

Survey Procedures

Sampling Stations

The routine sampling stations along Pryor Creek and the locations of the industries are shown in Figure 2 (Main Text). Special biological sampling stations are shown in Figure 5. Both routine and special biological sampling stations on Ft. Gibson Reservoir are shown in Figure 3. Description of the sampling stations follows. Numbers for sampling stations on both Pryor Creek and Ft. Gibson Reservoir are miles above the mouths of the 2 streams.

PS-1	Raw sewage to Pryor sewage treatment plant.
PS-2	Sewage treatment plant primary clarifier effluent.
PS-3	Sewage treatment plant trickling filter effluent.
PS-4	Sewage treatment plant secondary clarifier effluent.
PS-5	Sewage treatment plant lagoon effluent (Mile 13.5).
D-1	Deere & Co. lagoon influent.
D-2	Deere lagoon effluent (Mile 9.6).
B-1	Bestwall Gypsum Co. lagoon influent.
B-2	Bestwall lagoon effluent (Mile 8.0).
N-1	National Gypsum Co. lagoon influent.
N-2	National lagoon effluent (Mile 5.5).
G-1	GRDA steam plant effluent (Mile 5.2).
S-0.7	Creek which runs past sewage treatment plant lagoon at point beneath U. S. Highway 69 bridge. 13.3 miles above mouth of Pryor Creek.
P-0.0	Mouth of Pryor Creek.
P-1.0	One mile from mouth of Pryor Creek.
P-2.0	Just above regular sampling station, P-2.1.
P-2.1	At large bend in Pryor Creek.
P-3.0	Just above bridge at south edge Ordinance Works.

P-3.1	Bridge along south edge of Ordinance Works.
P-4.0	Pryor Creek along Ordinance Works burning grounds.
P-4.8	Above point where GRDA water line crosses creek.
P-4.9	0.3 miles below GRDA steam plant discharge.
P-5.4	Approximately half way between points where GRDA and National Gypsum effluents discharge into creek.
P-5.6	Bridge near north edge of Ordinance Works.
P-1.7	Between regular sampling stations, P-1.0 and P-2.1.
P-6.1	1.9 miles below Bestwall discharge, 0.6 miles above National Gypsum discharge.
P-6.4	At Highway 69A bridge.
P-8.6	Below railroad bridge just above low water bridge.
P-9.8	About 0.2 miles above Deere Co. discharge.
P-10.0	About 0.4 miles above Deere Co. discharge.
P-10.5	Pryor Creek at Tulsa water line crossing.
P-10.8	About 3.7 miles below sewage treatment plant.
P-14.0	Pryor Creek above confluence with sewage plant branch.
G-7.7	Grand River one hundred yards above Ft. Gibson Dam.
G-13.7	Grand River at Oklahoma Highway 51 bridge between second and third piers from west end.
G-19.2	About 2 miles above entrance to North Bay.
G-24.8	Grand River at Wagoner water intake.
G-28.8	One mile below Big Hollow Creek at point one-third of distance from west bank of Grand River.
G-31.9	In west channel of Grand River at Lower Spring Creek Isle below Three Fingers Bay.
G-35.2	About 1.5 miles below Brush Creek in center of river.

G-37.7	About 500 feet above confluence with Chouteau Creek.
G-39.0	Highway 33 bridge.
G-40.0	About 1,500 feet above Pryor Creek in center of river.
G-43.5	Just below low water dam.
SP	Spavinaw Creek at Oklahoma Highway 20 bridge.
BC	Big Cabin Creek at Oklahoma Highway 28 bridge.
CH	Chouteau Creek at Oklahoma Highway 33 bridge.

Sample Collection

Grab samples were collected from Pryor Creek and Ft. Gibson Reservoir.

Samples collected in Pryor Creek were usually taken in the center of the stream and at a point approximately one foot from the bottom when the depth was sufficient.

Samples from Grand River were taken by boat in the main channel. At Station G-40.0 samples were taken at only one depth because mixing was assumed to be adequate. Stations G-37.7 and G-35.2 were sampled at the bottom and 5 feet from the surface. The remaining stations on Grand River were sampled near the bottom, 5 feet from the surface, and half way between these depths.

All stream samples were obtained during the morning hours.

Industrial waste samples and those from the Pryor sewage treatment plant were composited to represent the day's waste. Samples from the sewage treatment plant and the John Deere lagoon influent and effluent were composited every 60 minutes for 24 hours. Samples at Bestwall and National Gypsum lagoon influent were composited every 30 minutes for 8 hours. GRDA composited 3 samples over an 8 hour shift.

The individual portions taken for the raw sewage composite sample at the sewage plant was proportioned according to raw sewage flow at the time of sampling. Raw sewage was pumped to the clarifier by either one or two pumps, depending on flow. When one pump was running equal individual portions were collected for the composite samples for the following treatment process effluents. When both pumps were operating twice as much individual portion sample was collected as when only one pump was running.

The flow from the industrial plants was relatively constant throughout the day, and equal individual portions were taken for the composite samples.

Samples for nitrogen determinations were preserved with concentrated sulfuric acid. Samples for phenol or cyanide determination were preserved with sodium hydroxide pellets and sulfide samples were preserved with zinc acetate. Bacteriological samples were kept in ice cooled cases until they reached the laboratory. A seperate unpreserved sample was taken for all other determinations.

Frequencies of sampling are shown by the dates in tables of analytical data.

Laboratory Facilities

Bacteriological samples were examined at the State Health Department Laboratory at Muskogee, Oklahoma. The examination was generally started the same day the samples were taken.

Samples for oil and chromium were shipped to the Public Health Service Sanitary Engineering Center, Cincinnati, Ohio prior to September 19, 1956 and subsequently were shipped to the U.S.G.S. laboratory at Tulsa for analysis. All other laboratory determinations on stream samples were made in two of the mobile laboratories of the Oklahoma Health Department and the U. S. Public Health Service. Biological examinations were made in the third trailer laboratory.

Field determinations were made for temperature, pH and dissolved oxygen by the person taking the sample.

Methods of Examination

All analyses made followed the recommendations of "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes," 10th Edition, or by other established methods for those examinations not covered by Standard Methods.

Biological methods employed are described in the individual sections of the complete biological report, Appendix B.

Types of determinations made are shown by the results reported in the tabulations of data.

Flow Measurements

The various flows and the means of measurement are outlined below:

Flow	Measuring Devices
Pryor sewage plant raw sewage	Calibrated water level recorder
Pryor sewage plant lagoon effluent	15" contracted rectangular weir
Deere lagoon effluent	90° V-notch weir
Bestwall lagoon effluent	3' suppressed rectangular weir
National Gypsum lagoon effluent	1.5' contracted rectangular weir
GRDA effluent	Current meter
Pryor Creek below P-4.8	U. S. G. S. water level recorder

A water level recorder was used in conjunction with each weir on the plant effluents.

The sum of average discharges of all upstream plants was used for the flow at various sampling points along Pryor Creek, except for flows below the GRDA steam plant to the mouth. For this section flows were obtained from the U.S.G.S. gaging station established below the GRDA plant during the survey.

APPENDIX D

Table D-1

Volume of Water in Pryor Creek

Section	Millions of Gallons	
	In Section	Cumulative
P-10.5 to Deere effluent (P-9.6)	2.67	2.67
Deere effluent to P-8.6	7.81	10.48
P-8.6 to Bestwall effluent (P-8.0)	4.22	14.70
Bestwall effluent to P-6.4	17.91	32.61
P-6.4 to P-5.6	4.46	37.07
P-5.6 to National Gypsum effluent (P-5.5)	0.39	37.46
National Gypsum effluent to P-5.4	1.03	38.49
P-5.4 to GRDA effluent (P-5.2)	1.30	39.79
GRDA effluent to P-4.8	0.90	40.69
P-4.8 to P-4.0	3.41	44.10
P-4.0 to P-3.1	3.93	48.03
P-3.1 to P-2.1	7.23	55.26
P-2.1 to P-1.0	16.92	72.18
P-1.0 to P-0.0	32.34	104.52

Table D-2

Time of Water Travel in Pryor Creek

Section	Days*	
	In Section	Cumulative
P-10.5 to Deere effluent (P-9.6)	6.1	6.1
Deere effluent to P-8.6	13.4	19.5
P-8.6 to Bestwall effluent (P-8.0)	7.2	26.7
Bestwall effluent to P-6.4	8.6	35.3
P-6.4 to P-5.6	2.2	37.5
P-5.6 to National Gypsum effluent (P-5.5)	0.2	37.7
National Gypsum effluent to P-5.4	0.4	38.1
P-5.4 to GRDA effluent (P-5.2)	0.5	38.6
GRDA effluent to P-4.8	0.2	38.8
P-4.8 to P-4.0	0.8	39.6
P-4.0 to P-3.1	1.0	40.6
P-3.1 to P-2.1	1.8	42.4
P-2.1 to P-1.0	4.1	46.5
P-1.0 to P-0.0	7.8	54.3
P-10.[illegible] to P-[illegible]	[illegible]	

*Complete displacement of water and no rainfall runoff are assumed. Total flow consists of discharges from plants along the creek.

Table D-3

Pryor Creek - Discharge cfs

Day	1953 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.1	1.5	0.5	5.5	168	7.2	0	0	0	0	1.7	0.5
2	0.1	1.3	0.8	5.5	92	6.2	0	0	0	0	1.4	0.5
3	0.1	1.1	19	5.8	66	5.5	0.1	0	5.0	0	1.0	1.0
4	0.1	0.9	207	5.5	53	5.0	0.9	0	9.8	461	0.6	38
5	0.1	0.8	79	640	45	5.0	0.9	0	1.7	117	0.5	37
6	0.1	0.6	32	1,190	46	6.2	0.8	0	0.6	59	0.3	18
7	0.1	0.6	17	194	56	6.0	49	0	0.3	18	0.2	9.8
8	0.1	0.5	11	104	60	10	7.8	0	0.1	8.1	0.1	5.9
9	0.1	0.5	8.2	72	47	8.0	3.8	0	0.1	3.7	0.1	3.9
10	0.1	0.6	6.8	52	36	5.8	2.3	0	0	2.2	0.1	2.8
11	0.1	0.8	6.0	36	28	4.5	1.9	0	0	1.5	0.1	2.4
12	0.1	0.6	5.8	34	314	3.5	2.9	13	0	1.0	0.1	1.7
13	0.1	0.6	18	36	1,120	2.9	3.3	7.5	0	0.6	0	1.4
14	0.1	0.6	670	30	187	2.3	1.9	1.9	0	0.5	0	1.0
15	0.1	0.5	299	23	117	1.5	1.7	0.5	0	0.3	0	0.9
16	0.1	0.3	70	16	119	1.1	1.7	0.2	0	0.1	0	0.7
17	0.1	0.2	51	12	200	0.8	1.3	0.1	0	0.1	0	0.6
18	0.2	0.1	291	432	106	0.6	0.9	5.3	0	0.1	0	0.5
19	0.2	0.1	151	261	894	0.5	0.8	2.7	0	0	0.2	0.3
20	0.2	0.1	62	84	440	0.3	8.2	2.1	0	0	52	0.2
21	0.2	0.1	38	51	105	0.2	3.5	0.9	0	0	64	0.2
22	0.3	0.1	24	37	70	0.1	1.7	0.5	0	0.1	22	0.1
23	1.5	0.1	16	170	53	0.3	0.9	0.1	0	0.5	11	0.1
24	1.7	0.1	12	3,410	40	0.3	0.6	0.1	0	0.2	5.9	0.1
25	1.1	0.1	9.5	2,350	32	0.2	0.3	0	0	0.6	3.9	0.1

Table D-3 (Con't.)

Pryor Creek - Discharge cfs

	1953											
Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
26	0.9	0.2	8.0	328	26	0.1	0.2	0	0	2.0	2.6	0.1
27	0.6	0.2	7.5	137	19	0.1	0.1	0	0	1.2	1.7	0.1
28	4.0	0.2	6.8	112	15	0	0.1	0	0	0.7	1.5	0.1
29	2.9		6.2	549	12	0	0	0	0	0.9	1.2	0.1
30	2.1		6.0	433	9.8	0	0	0	0	2.8	0.9	0.1
31	1.7		6.0		8.5		0	0		2.2		0.1
Mean	0.62	0.48	69.2	361	148	2.81	3.15	3.15	0.59	22.1	5.77	4.14
	1954											
1	0	0.7	0.9	1.7	790	222	0	0	0	0	0	0
2	0	0.9	0.7	1.4	569	64	0	0	0	0	.2	0
3	0	0.9	0.5	1.2	370	66	0	0	0	0	.2	0
4	0	0.9	0.5	0.9	86	36	0	0	0	0	.2	0
5	0	0.9	0.3	0.9	49	18	0	0	0	0	.1	0
6	0	0.7	0.3	0.7	33	9.8	0	0	0	0	.1	0
7	0	0.7	0.2	0.5	25	6.2	0	0	0	0	.1	0
8	0	0.7	0.2	0.3	33	4.4	0	0	0	0	0	0
9	0	0.7	0.2	0.2	16	2.8	0	0	0	0	0	0
10	0	0.7	0.1	0.1	11	2.0	0	4.7	0	0	0	0
11	0	0.6	0.1	0.3	8.6	1.4	0	5.4	0	0	0	0
12	0	0.5	0.1	0.3	7.5	3.2	0	2.8	0	0	0	0
13	0	0.5	0.1	0.5	6.6	3.0	0	1.2	0	0	0	0

Table D-3 (Con't.)

Pryor Creek - Discharge cfs

	1954											
Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
14	0	0.5	0	0.6	5.6	14	0	.6	0	0	0	0
15	0	0.3	0	0.5	4.9	19	0	.3	0	0	0	0
16	0	0.3	0	0.2	4.2	8.4	0	.1	0	0	0	0
17	0	0.3	0	0.1	3.9	4.6	0	0	0	0	0	0
18	0	0.2	0	0	3.0	3.0	0	0	0	0	0	0
19	0.1	0.5	0	0	11.0	2.0	0	0	0	0	0	0
20	0.1	0.6	0	0	8.1	1.4	0	22	0	0	0	0
21	0.1	0.5	0	0	4.9	1.0	0	2.9	0	0	0	0
22	0.1	0.3	0	0.2	3.0	.6	0	.7	0	0	0	0
23	0.1	0.3	0.4	0.3	2.2	.5	0	.2	0	0	0	0
24	0.1	0.2	0.6	0.1	1.8	.2	0	.1	0	0	0	0
25	0.2	0.3	1.0	0	2.0	.1	0	0	0	.8	0	0
26	0.3	1.0	0.6	0	44	.1	0	0	0	.6	0	0
27	0.6	1.2	0.5	0	64	0	0	0	0	.3	0	9.8
28	0.5	1.0	0.3	0	19	0	0	0	0	.1	0	14.0
29	0.5		0.2	0	8.4	0	0	0	0	0	0	6.2
30	0.6		1.8	287	300	0	0	0	0	0	0	4.6
31	0.6		2.0		215		0	0		0		4.2
Mean	0.13	0.60	0.37	9.93	87.4	16.5	0	1.32	0	.06	.03	1.25

Table D-3 (Con't.)

Pryor Creek - Discharge cfs

Day	1955 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.4	0	2.4	61	0.9	19	5.5	0	2.6	753		
2	2.6	0	1.8	93	.7	12	3.2	0	2.2	42		
3	2.2	0	1.7	58	.6	9.2	2.0	0	1.2	17		
4	1.7	0	1.4	36	.7	7.4	1.3	0	.7	39		
5	2.2	.1	.9	25	.9	8.3	1.0	0	.5	1,300		
6	2.4	.1	.7	18	.7	7.6	.7	15	.3	927		
7	1.8	.1	.6	14	.5	10	.5	7.7	.2	78		
8	1.5	.1	.3	11	.2	8.3	.3	3.6	.1	30		
9	1.4	0	.2	8.9	.1	5.5	.2	3.6	0	16		
10	1.2	0	.1	8.4	.3	4.1	.1	4.7	83	10		
11	1.0	0	.1	13	.6	3.2	.1	3.5	48	7.4		
12	.9	0	0	27	3.7	2.5	0	5.7	26	5.7		
13	.7	0	0	25	2.2	2.3	0	3.0	8.5	4.5		
14	.6	0	0	20	1.2	2.3	0	1.2	4.1	3.4		
15	.3	0	89	23	.7	118	0	.6	2.0	2.6		
16	.2	0	59	18	.5	88	0	.4	1.0	2.0		
17	.2	0	13	12	.3	18	0	.2	.7	1.4		
18	.2	0	6.6	8.4	.2	7.1	0	.1	.5	1.0		
19	.2	29	4.2	6.4	.5	3.9	0	0	.3	.7		
20	.2	60	295	5.4	.7	2.3	0	0	.2	.4		
21	.2	40	1,010	4.4	1.0	1.3	0	0	.1	.3		
22	.2	13	135	4.2	1.5	1.0	0	0	.1	.2		
23	.1	6.9	164	3.7	33	33	0	0	.1	.2		
24	.1	4.6	95	3.4	18	38	0	2.0	0	.1		
25	.1	3.7	54	3.2	22	9.6	0	10	.1	.1		

Table D-3 (Con't.)

Pryor Creek - Discharge cfs

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						1955						
26	.1	3.4	33	2.2	26	4.7	0	4.2	.1	0		
27	0	3.2	20	1.8	16	3.6	0	1.7	.1	0		
28	0	2.6	15	1.5	468	2.6	0	.8	.1	0		
29	0		12	1.2	640	26	0	151	1.8	0		
30	0		10	1.0	73	11	0	29	1,740	0		
31	0		9.7		33		0	5.8		0		
Mean	0.83	5.69	65.6	17.3	43.5	15.7	0.48	8.19	64.2	105		
						1956						
1	0	.3		0	1.7	7.0	20		0	0	0	0
2	0	.4		0	2.2	5.0	9.8		0	0	0	0
3	0	.5		0	29	26	5.4		0	0	0	0
4	0	.5		0	16	34	4.0		0	0	0	0
5	0	.5		0	8.8	16	2.9		0	0	0	0
6	0	.4		0	6.0	25	2.0		0	0	0	0
7	0	.4		0	4.2	18	1.5		0	0	0	0
8	0	.4		0	2.5	12	1.0		0	0	0	0
9	0	.4		0	1.9	7.3	.7		0	0	0	0
10	0	.3		0	1.2	4.5	.5		0	0	0	0
11	0	.3		0	.9	2.7	.3		0	0	0	0
12	0	.3		0	.7	1.5	.3		0	0	0	0

Table D-3 (Con't.)

Pryor Creek - Discharge cfs

	1956											
Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
13	0	.2		0	.5	1.2	.2		0	0	0	0
14	0	.1		0	230	1.0	.1		0	0	0	0
15	0	.1		0	1,640	.8	0	0	0	0	0	0
16	0	.1		282	162	.7	0	0	0	0	0	0
17	0	.1		40	50	.5	0	0	0	0	0	0
18	0	.1		16	23	.4	0	0	0	0	0	0
19	0	.1		8.8	12	.3	0	0	0	0	0	0
20	0	.1		6.2	8.2	.2	0	0	0	0	0	0
21	0	.1		4.2	5.7	.1	0	0	0	0	0	0
22	0	0		3.1	4.5	0	0	0	0	0	0	0
23	.2	0		2.0	15	.1	0	0	0	0	0	0
24	.2	0		1.7	946	1.1	0	0	0	0	0	0
25	.3	0		1.3	210	2.0	0	0	0	0	0	0
26	.2	0		1.2	65	32	0	0	0	0	0	0
27	.2	0		1.0	36	19	0	0	0	0	0	0
28	.2	0		.8	35	826	0	0	0	0	0	0
29	.2	0		.8	25	289	0	0	0	0	0	0
30	.2			.7	13	47	0	0	0	0	0	0
31	.2				9.4		0	0		0		0
Mean	.06	.20	0	12.3	115	46.0	1.57	0	0			

Table D-3 (Con't.)

Pryor Creek - Discharge cfs

	1957											
Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	0	7.2	1.5									
2	0	5.3	1.0									
3	0	3.3	.9									
4	0	2.0	.6									
5	0	1.7										
6	0	1.3										
7	0	1.0										
8	0	2.8										
9	0	7.6										
10	0	7.5										
11	0	12										
12	0	6.8										
13	0	4.7										
14	0	2.7										
15	0	3.2										
16	0	13										
17	0	24										
18	0	22										
19	0	11										
20	0	6.5										
21	0	4.5										
22	0.2	3.6										
23	0	2.9										
24	0	2.2										
25	0	1.9										

Table D-3 (Con't.)

Pryor Creek - Discharge cfs

Day	1957											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
26	0	1.9										
27	0	1.7										
28	0	1.5										
29	0	-										
30	0	-										
31	0	-										
Mean	0.01	5.92										

Table D-4

Grand River at Langley, Okla. - Discharge cfs

Day	1953											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	240	110	66	4,330	5,150	4,450	1,930	105	264	91	89	-
2	1,820	1,710	1,370	4,290	2,350	4,210	2,530	86	155	72	87	55
3	480	1,720	1,350	3,770	1,070	4,090	760	1,060	69	75	85	-
4	350	1,840	1,020	1,780	4,710	3,580	100	2,040	65	74	87	122
5	1,950	2,140	810	650	4,550	3,440	90	759	62	66	87	-
6	1,750	1,810	710	3,900	5,020	1,340	2,990	1,260	69	-	87	51
7	1,860	150	140	4,600	4,730	310	890	1,950	70	-	87	-
8	1,760	87	70	4,880	4,750	4,440	2,080	109	85	-	87	950
9	2,170	3,050	1,250	4,880	3,780	4,580	700	84	69	-	309	1,200
10	260	2,900	1,370	4,700	1,320	4,280	250	295	63	-	677	1,350
11	90	2,100	1,180	3,210	4,900	3,950	80	2,060	64	-	558	1,620
12	2,040	1,800	1,010	1,790	5,540	3,640	210	1,320	62	-	585	380
13	2,250	1,950	1,100	4,460	6,490	1,680	240	1,540	60	57	632	95
14	2,500	130	970	5,210	5,200	220	280	2,050	61	-	150	1,340
15	2,220	91	200	5,030	5,470	3,650	340	127	62	-	70	1,660
16	2,700	1,270	2,350	5,060	2,940	2,820	350	94	63	-	74	1,520
17	210	1,250	2,680	6,020	1,110	2,740	450	213	63	-	72	1,720
18	80	2,060	2,480	3,230	4,900	2,310	90	78	63	-	70	1,510
19	1,420	1,860	2,630	1,140	5,450	2,130	70	72	64	-	70	620
20	2,260	1,600	2,080	4,720	5,360	140	430	65	63	-	242	100
21	1,500	150	1,000	5,370	5,650	70	2,080	63	62	-	75	1,900
22	2,490	93	140	6,180	4,780	270	2,990	63	62	388	-	1,780
23	1,950	1,100	2,480	6,240	3,230	350	2,180	63	63	100	-	1,730
24	150	1,660	3,160	5,210	1,480	1,830	1,190	64	63	93	-	745
25	90	1,300	3,540	3,120	5,270	2,610	494	63	61	91	-	120

Table D-4 (contd)

Grand River at Langley, Okla. - Discharge cfs

	1953											
Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
26	1,690	910	3,950	1,810	5,400	3,540	102	62	61	93	55	145
27	2,070	1,360	3,320	4,890	4,880	1,040	2,710	61	61	95	-	90
28	1,820	123	1,380	5,840	4,840	96	2,890	99	131	91	-	1,470
29	1,320	-	470	4,740	3,900	1,240	3,090	64	81	93	-	1,040
30	1,740	-	3,840	6,080	1,580	1,150	1,540	61	72	93	-	1310
31	240	-	4,040	-	750	-	2,190	170	-	91	-	1,310
Mean	1,402	1,297	1,682	4,238	4,082	2,340	1,171	523	77.1	81.2	159	843
	1954											
1	110	72	55	135	2,100	2,850	4,610	63	158	55	2,400	1,740
2	89	72	61	65	2,680	2,880	4,440	67	76	55	2,600	1,590
3	-	72	61	69	5,100	2,120	300	555	200	55	2,460	1,680
4	-	72	59	245	5,290	2,620	80	730	70	268	2,440	205
5	-	70	59	115	5,580	915	125	580	59	77	2,530	115
6	55	68	57	82	5,820	240	4,540	250	59	54	235	1,500
7	-	66	55	88	5,430	3,530	5,170	98	285	52	90	1,800
8	-	68	59	88	4,000	3,500	4,080	63	70	50	2,400	1,640
9	-	69	57	90	2,900	3,620	4,120	59	59	55	2,660	1,630
10	-	69	57	100	5,600	3,640	735	198	57	55	2,720	1,500
11	744	71	59	227	6,440	3,790	71	568	59	340	2,910	170
12	915	61	57	125	5,980	1,590	4,980	445	55	150	2,840	90
13	585	59	61	80	6,020	620	4,300	318	50	750	262	1,730

Table D-4 (Contd)

Grand River at Langley, Okla. - Discharge cfs

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						1954						
14	83	57	59	71	5,960	3,900	3,100	71	54	1,020	88	1,650
15	77	1,160	59	73	5,090	4,030	1,690	65	105	985	2,530	2,000
16	75	1,440	1,470	1,570	3,660	4,820	1,570	1,260	68	190	2,400	2,420
17	74	1,460	1,420	170	5,900	5,120	245	1,510	55	63	2,170	2,620
18	81	1,490	1,460	61	5,920	5,210	69	1,630	72	825	1,940	360
19	81	1,500	1,450	1,440	3,800	3,540	1,660	1,390	75	1,200	1,780	110
20	81	165	128	1,430	3,180	1,670	1,200	112	1,210	1,820	230	2,300
21	292	69	55	1,440	3,320	5,010	1,520	67	100	1,770	1,560	2,580
22	77	1,340	1,290	1,980	925	5,900	1,920	63	59	1,760	1,980	2,620
23	74	1,470	1,460	2,000	892	6,110	1,220	575	57	190	1,940	2,270
24	75	1,440	1,420	127	3,350	5,430	88	205	55	63	1,680	380
25	75	1,510	1,360	61	3,410	4,270	71	595	59	2,580	190	145
26	77	1,450	1,410	1,960	3,200	700	338	1,260	59	2,520	1,610	88
27	77	138	140	2,320	3,390	78	495	1,510	90	2,530	215	2,430
28	75	61	57	2,180	3,630	3,960	805	160	66	2,720	69	2,840
29	72	-	1,410	2,400	658	4,460	365	69	55	2,620	1,720	1,810
30	72	-	1,500	3,190	345	4,400	450	2,190	55	188	2,080	2,380
31	72	-	1,500	-	410	-	75	868	-	67	-	1,560
Mean	144	559	594	799	3,870	3,351	1,756	568	118	811	1,691	1,482
						1955						
1	180	1,840	3,050	4,090	75	3,640	17,900	3,600	3,340	2,230	2,970	3,420
2	130	1,780	2,980	275	3,720	4,570	13,700	3,860	3,200	1,020	3,000	3,140
3	2,340	2,090	2,940	80	3,940	4,980	12,700	3,190	2,100	2,660	3,040	260
4	4,620	1,780	2,970	3,980	2,920	3,900	8,660	2,560	527	3,680	3,220	92

Table D-4 (contd)

Grand River at Langley, Okla. - Discharge cfs

Day	1955											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
5	4,630	180	290	3,980	2,900	3,200	7,640	2,320	724	3,690	335	3,320
6	4,260	98	85	3,640	2,760	4,860	7,870	540	3,380	3,850	92	3,680
7	4,420	1,750	2,880	3,480	235	5,210	8,270	130	4,100	4,040	1,790	3,860
8	3,890	1,920	3,080	3,660	82	5,520	8,120	2,810	4,250	4,680	1,770	3,920
9	2,490	2,210	3,260	270	2,040	5,340	7,030	2,910	4,190	2,220	2,270	3,540
10	5,240	2,460	3,620	88	2,440	5,120	5,620	3,190	2,490	3,620	2,280	245
11	6,290	2,660	3,480	3,580	2,540	3,680	7,720	2,990	767	3,750	1,940	88
12	6,290	295	280	4,100	1,800	2,640	7,220	2,660	3,230	3,540	226	2,860
13	5,850	82	80	4,380	1,820	5,030	6,510	240	3,360	3,530	112	3,280
14	7,630	1,920	3,130	4,000	215	5,340	4,340	73	3,910	3,640	1,820	3,460
15	5,970	2,520	3,480	4,210	78	5,640	4,360	2,390	3,700	2,760	1,920	3,450
16	4,410	2,440	3,360	350	1,980	5,480	305	2,460	2,810	1,500	1,570	3,190
17	6,150	2,620	3,460	88	2,220	5,040	100	2,530	262	3,460	1,540	230
18	3,480	2,920	3,360	4,060	2,800	4,230	3,630	2,660	69	4,090	1,640	88
19	3,500	360	250	4,280	2,580	3,240	3,880	2,530	2,980	4,140	200	3,190
20	3,560	90	150	4,240	2,780	5,010	4,060	240	3,140	4,460	80	3,560
21	3,300	3,240	3,180	4,310	240	3,560	4,320	71	3,350	4,610	1,950	3,410
22	290	4,870	2,920	4,490	82	3,500	4,510	2,280	3,620	2,670	2,280	3,640
23	140	5,220	3,520	300	2,000	3,560	194	2,720	3,840	1,080	2,100	3,280
24	4,100	4,390	3,810	82	2,290	3,620	82	2,660	2,530	4,000	205	280
25	2,000	4,390	3,440	4,310	2,430	312	4,430	2,380	930	4,450	1,380	98
26	2,240	285	250	4,220	2,720	115	4,740	2,220	3,590	3,160	182	92
27	2,250	85	78	4,160	3,440	4,440	4,740	230	3,950	3,370	85	3,090
28	1,720	3,290	3,260	4,080	4,130	7,450	4,340	75	4,210	3,250	2,210	4,080

Table D-4 (contd)

Grand River at Langley, Okla. - Discharge cfs

	1955											
Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
29	180	-	3,850	3,820	2,540	17,600	3,890	2,420	4,750	265	2,320	4,520
30	88	-	3,940	300	2,520	28,600	700	3,140	3,850	82	2,450	3,700
31	1,860	-	4,360	-	4,300	-	129	2,870	-	3,440	-	225
Mean	3,339	2,064	2,542	2,897	2,148	5,481	5,539	2,097	2,905	3,127	1,566	2,429

Table D-4 (Con't.)

Grand River at Langley, Okla. - Discharge cfs

	1956											
Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	85	508	749	175	370	2,660	80	2,410	65	55		
2	82	328	790	1,240	265	255	3,360	1,370	63	55		
3	2,890	115	247	890	390	82	3,460	2,050	63	57		
4	2,480	79	99	1,140	620	2,780	278	723	379	57		
5	2,060	79	856	1,190	155	3,100	2,870	175	850	55		
6	595	404	700	1,380	126	3,080	3,090	3,270	107	55		
7	115	385	797	200	735	3,260	285	3,360	82	55		
8	75	355	621	90	670	2,910	71	3,040	78	55		
9	498	200	548	1,200	735	230	2,980	3,360	80	55		
10	504	100	245	945	605	75	3,100	2,480	78	55		
11	585	75	120	825	1,040	3,010	2,960	200	122	55		
12	606	77	893	830	97	3,040	3,380	71	636	55		
13	300	362	944	805	81	2,940	3,600	3,410	2,320	55		
14	110	410	888	180	1,930	2,870	1,330	2,900	2,690	59		
15	73	555	1,150	125	5,380	2,910	375	3,630	388	59		
16	315	626	642	550	5,330	240	2,500	4,140	89	57		
17	701	972	181	645	5,340	75	2,360	3,590	1,570	57		
18	644	190	110	455	5,620	2,790	1,600	1,010	1,660	55		
19	246	90	400	675	4,450	2,790	832	176	1,660	57		
20	340	918	777	605	3,000	2,750	865	80	326	59		
21	110	987	886	190	4,790	2,780	106	71	1,370	63		
22	70	1,060	667	96	5,380	2,980	73	67	240	61		
23	625	1,550	412	585	4,690	185	575	63	82	61		
24	506	1,460	136	905	3,130	73	1,300	113	374	59		
25	570	252	136	810	3,000	3,130	2,170	63	562	61		

Table D-4 (Con't.)

Grand River at Langley, Okla. - Discharge cfs

	1955											
Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
26	663	109	607	785	254	2,680	2,520	61	730	61		
27	625	1,410	649	495	85	3,090	2,460	118	961	69		
28	165	1,380	543	175	2,960	2,450	680	430	1,140	76		
29	82	1,410	1,160	90	3,090	2,640	150	524	69			
30	675		845	575	283	1,260	1,970	889	61			
31	712		323		2,840		3,200	91				
Mean	584	567	585	628	2,176	2,104	1,761	1,433	630	56		

Table D-5

Grand River at Chouteau, Oklahoma
Discharge - cfs

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	1956											
1	405	750	1,320	440	410	2,970	1,320	3,110	291	120	97	74
2	185	510	715	328	475	2,600	440	2,420	112	103	81	74
3	132	315	715	940	390	505	3,370	1,860	85	101	80	78
4	2,370	294	450	958	444	480	3,080	2,100	83	93	116	2,770
5	2,260	169	165	1,200	640	3,070	455	763	180	87	127	522
6	1,760	132	665	1,120	350	3,260	2,860	315	730	83	107	164
7	570	225	725	1,300	188	3,460	2,860	3,340	270	80	87	116
8	319	390	840	370	647	3,560	390	3,260	103	81	78	134
9	156	385	635	172	730	2,980	235	3,120	85	78	72	172
10	330	290	590	965	825	685	2,920	3,360	83	78	72	127
11	507	215	425	895	675	720	3,070	2,300	85	78	76	101
12	548	137	155	754	1,170	3,160	3,100	350	85	78	76	99
13	590	93	550	783	351	3,060	3,500	179	429	76	78	237
14	340	130	1,020	725	650	2,950	3,290	3,350	2,170	102	78	679
15	282	375	875	441	10,900	2,860	1,260	3,150	2,550	134	76	702
16	146	510	1,240	2,320	7,420	2,790	455	3,700	382	116	74	263
17	200	585	681	844	6,130	460	2,570	4,200	244	91	69	109
18	765	900	400	670	5,960	360	2,240	3,490	1,300	85	69	590
19	720	425	155	472	5,440	2,820	1,610	1,060	1,580	80	71	605
20	343	160	125	665	3,950	2,740	890	369	1,620	83	69	602
21	327	555	725	584	3,430	2,740	860	174	364	83	112	1,120
22	295	920	908	340	5,240	2,870	290	132	1,250	81	93	1,360
23	151	965	742	146	5,300	2,780	170	107	340	80	91	298
24	465	1,460	455	400	3,660	455	560	97	242	76	116	127
25	510	1,370	260	931	3,180	972	1,540	89	279	71	95	1,060

Table D-5 (Con't.)

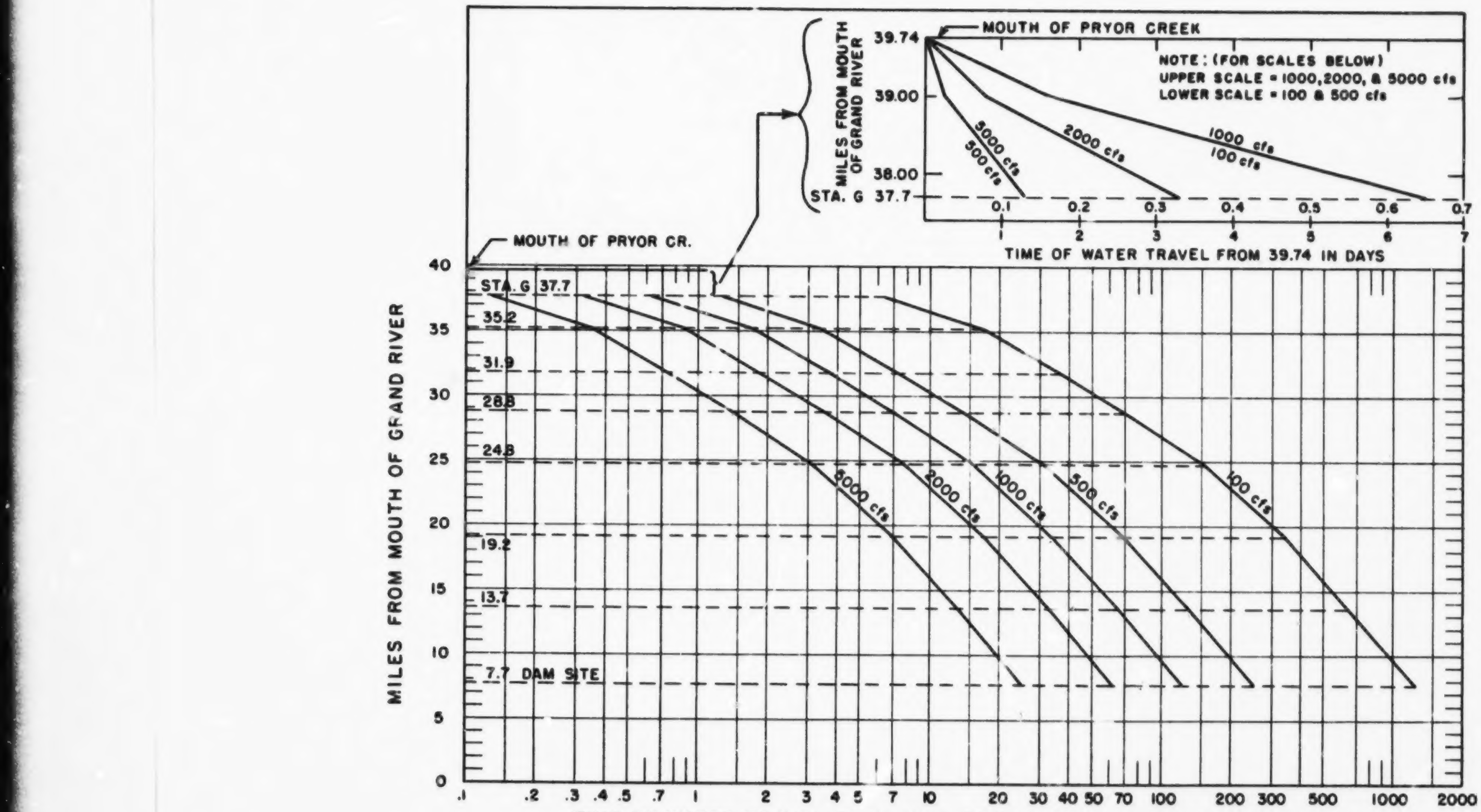
Grand River at Chouteau, Oklahoma
Discharge - cfs

	1956											
Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
26	571	452	140	843	2,800	3,900	2,420	127	549	72	85	297
27	657	160	258	840	500	3,240	2,580	101	674	69	76	2,160
28	640	1,050	652	555	361	3,180	2,520	80	890	71	76	2,500
29	355	1,280	475	315	2,900	2,560	780	304	1,180	69	76	2,200
30	159		1,180	205	2,760	2,550	335	499	238	99	72	330
31	490		1,100		490		2,000	833		120		144
Mean	566	524	624	717	2,528	2,359	1,741	1,562	616	87.7	84.8	639
	1957											
1	1,560	2,440	4,510									
2	302	360	3,430									
3	132	204	408									
4	114	156										
5	112	132										
6	109	765										
7	101	380										
8	99	448										
9	101	1,210										
10	99	405										
11	93	260										
12	95	3,300										
13	97	3,240										

Table D-5 (Con't.)

Grand River at Chouteau, Oklahoma
Discharge - cfs

	1957											
Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
14	97	3,130										
15	125	4,060										
16	500	4,750										
17	388	705										
18	275	458										
19	240	3,370										
20	127	3,520										
21	116	3,860										
22	258	3,930										
23	718	3,890										
24	520	408										
25	800	199										
26	1,340	193										
27	300	1,660										
28	150	3,920										
29	2,870	-										
30	2,700											
31	2,690											
Mean	556	1,834										



TIME OF WATER TRAVEL IN FT. GIBSON LAKE AT VARIOUS FLOWS

FIGURE D-1